THE UNIVERSITY OF ALBERTA

THE RAINBOW TROUT POPULATIONS (*SALMO GAIRDNERI*, RICHARDSON) AND OTHER FISH OF THREE STREAMS IN THE FOOTHILLS OF ALBERTA

by

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The rainbow trout populations (*Salmo gairdneri*, Richardson) and other fish of three streams in the foothills of Alberta," submitted by Karl George Dietz in partial fulfilment of the requirements for the degree of Master of Science.

Date ...Sept. 7, 1971...

ABSTRACT

During the summers of 1969 and 1970 the populations of rainbow trout (*Salmo gairdneri*, Richardson) in three headwater tributaries of the McLeod River, Alberta, were sampled and observed. The work was part of a study designed to measure and evaluate the effects of pulpwood logging on the aquatic environment of the streams. In 1970, estimates of the size of the populations in the creeks before logging were made. Descriptive features of the rainbow trout populations such as their growth rates, age structures, fecundities and distribution, together with information on their life history, were gathered. The abundance, distribution and growth of Dolly Varden (*Salvelinus malma*) and mountain whitefish (*Prosopium williamsoni*) were noted. The possible effects of clearcut logging on the fishery resource of the three creeks are discussed.

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Figure | Page

INTRODUCTION

In Alberta the densely forested foothills region constitutes an important recharge area for some of the major river systems of the province. At the same time the foothills are the source of raw materials for two of Alberta's burgeoning primary industries--the manufacture of woodpulp and the strip mining of coal. The region is also relatively rich in wildlife and aesthetic qualities and will be of greater social importance as a recreational area in the future.

Harvestable timber, being an integral part of the ecosystem of the mountain streams, is intimately associated with their populations of game fish and their primary food source, the aquatic insects. Logging of a watershed and other associated activities such as road construction represent a disturbance of the ecosystem and consequently may be of detriment to the welfare of the fish inhabiting the nearby streams.

Most of the studies of the effects of timber harvest on the fishery resource have concentrated on changes in the spawning bed environment and their effect on the reproduction of salmonids (e.g., Sheridan, 1962; Koski, 1966; McNeil, 1966) and very few have dealt with changes in the size of resident salmonid populations brought about by logging (see Hall and Lantz, 1969).

A comprehensive investigation of the effects of pulpwood extraction on the aquatic resources of two western Alberta trout streams is the objective of the TRI-Creeks watershed project. Three relatively undisturbed watersheds, Wampus, Deerlick and Eunice Creeks, have been

under study since 1965 and data on physical and biotic factors in the streams have been accumulating. Currie (1969) described the hydrogeology of the basin and Zelt (1970) studied the mayfly and stonefly fauna of one of the streams.

The current plans are to divide the study area into two portions on the basis of its surficial geology and to test the effect of buffer strips of timber in conjunction with two methods of logging. The term "buffer strip" refers to a band of riparian vegetation that is retained for the purpose of protecting the habitat of aquatic organisms. Wampus Creek will be patch cut and buffer strips will be retained only in the lower reaches of the stream whereas Deerlick Creek is to be clear cut and buffers are to be left only in the upper portion of the creek. Eunice Creek has the function of a control stream. Commencement of logging is planned for 1978.

The current hydrological, meteorological, biological and ground-water monitoring program will be continued for several years following logging.

The primary objectives of this study were to estimate the abundance and distribution of the fish stocks in Wampus, Deerlick and Eunice Creeks and to describe certain aspects of their biology in some detail. Biological information from some fish of the McLeod River was gathered for the purpose of comparison with populations in the tributaries.

DESCRIPTION OF STUDY AREA

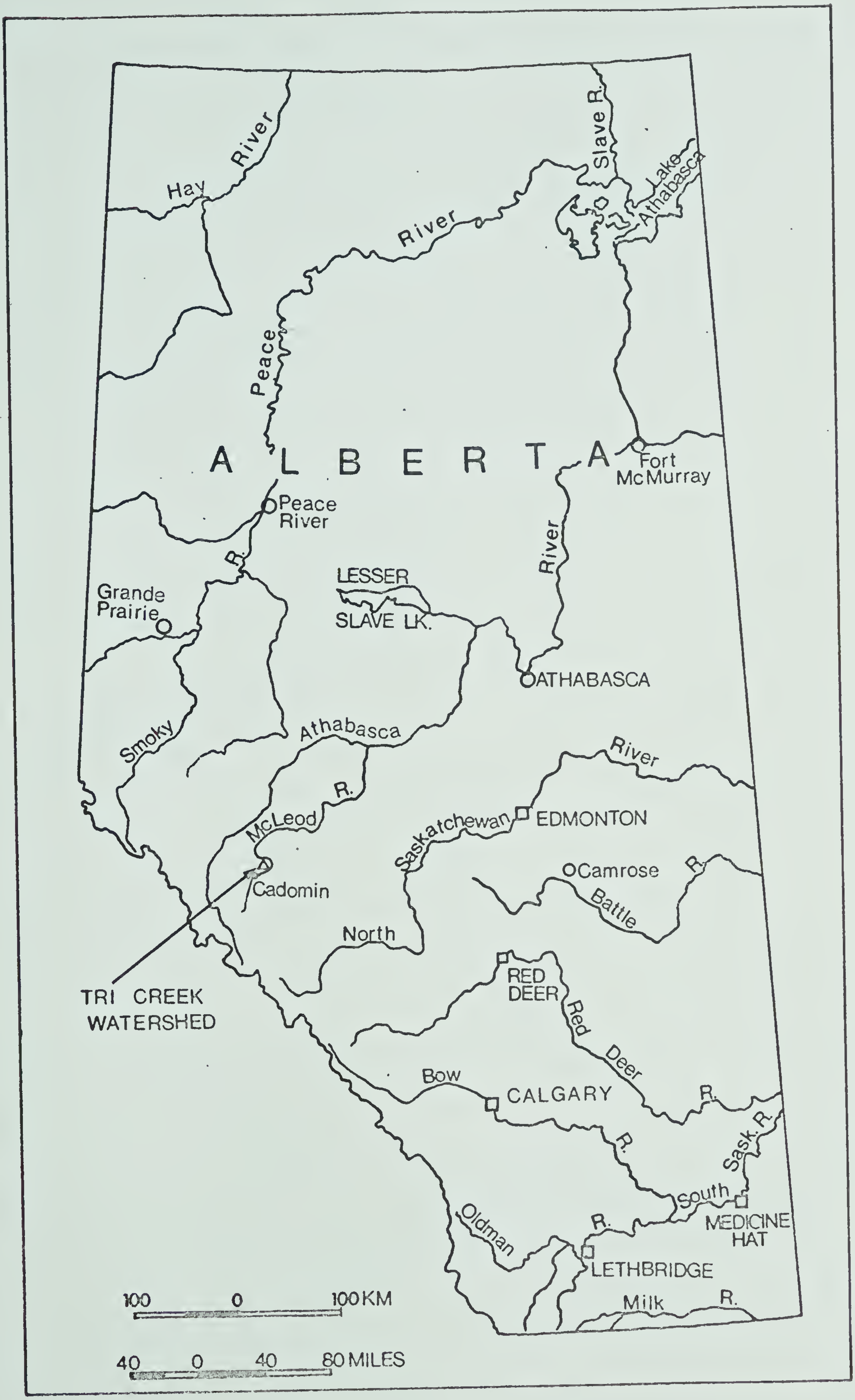
The study area has previously been described as follows (Currie, 1969; Zelt, 1970): The name TRI Creek basin, situated at 53° 09' north latitude and 117° 15' west longitude, refers to an area, 23 square miles (60 square kilometers) in extent, that is drained by three northward flowing streams, Wampus, Deerlick and Eunice Creeks (Figures 1 and 2). The streams are tributaries of the McLeod River, itself a tributary of the Athabasca which empties into the Arctic Ocean via the Mackenzie River. Elevations in the area range from 4,133 to 5,527 feet (1,260 to 1,685 m) resulting in an average gradient of the main stream channels of 265 feet per mile (50.2 m per kilometer).

The surficial geology of the basin is comprised mainly of glacial tills (an unsorted, unstratified material with a wide range in grain size) and glaciolacustrine deposits consisting of silt (size range 4-64 microns), which is easily eroded after removal of the vegetative cover (Currie, 1969).

The basin lies in the subalpine forest zone characterized by the following dominant trees: lodgepole pine (*Pinus contorta*, Dougl), white spruce (*Picea glauca*, Voss), black spruce (*Picea mariana*, B.S.P.) and alpine fir (*Abies lasiocarpa*, Nutt) (Figure 3).

Meadows of stunted willows (*Salix* spp.), swamp birch (*Betula pumila*, L.), and sedges (*Carex* spp.) are found in areas of groundwater discharge (Figure 4).

Figure 1. Index map.



ALBERTA
Hay River
Peace River
Slave R.
Lake Athabasca
Fort McMurray
River
Peace River
R.
Grande Prairie
LESSER SLAVE LK.
ATHABASCA
Smoky
Athabasca
McLeod R.
River
Saskatchewan
EDMONTON
Camrose
Battle R.
Cadomin
North
TRI CREEK WATERSHED
RED DEER
Red Deer R.
Bow
CALGARY
R.
Sask. R.
South
MEDICINE HAT
Oldman R.
LETHBRIDGE
Milk R.
100 0 100 KM
40 0 40 80 MILES

Figure 2. Map of study area with stream sections.

TRI CREEK WATERSHED

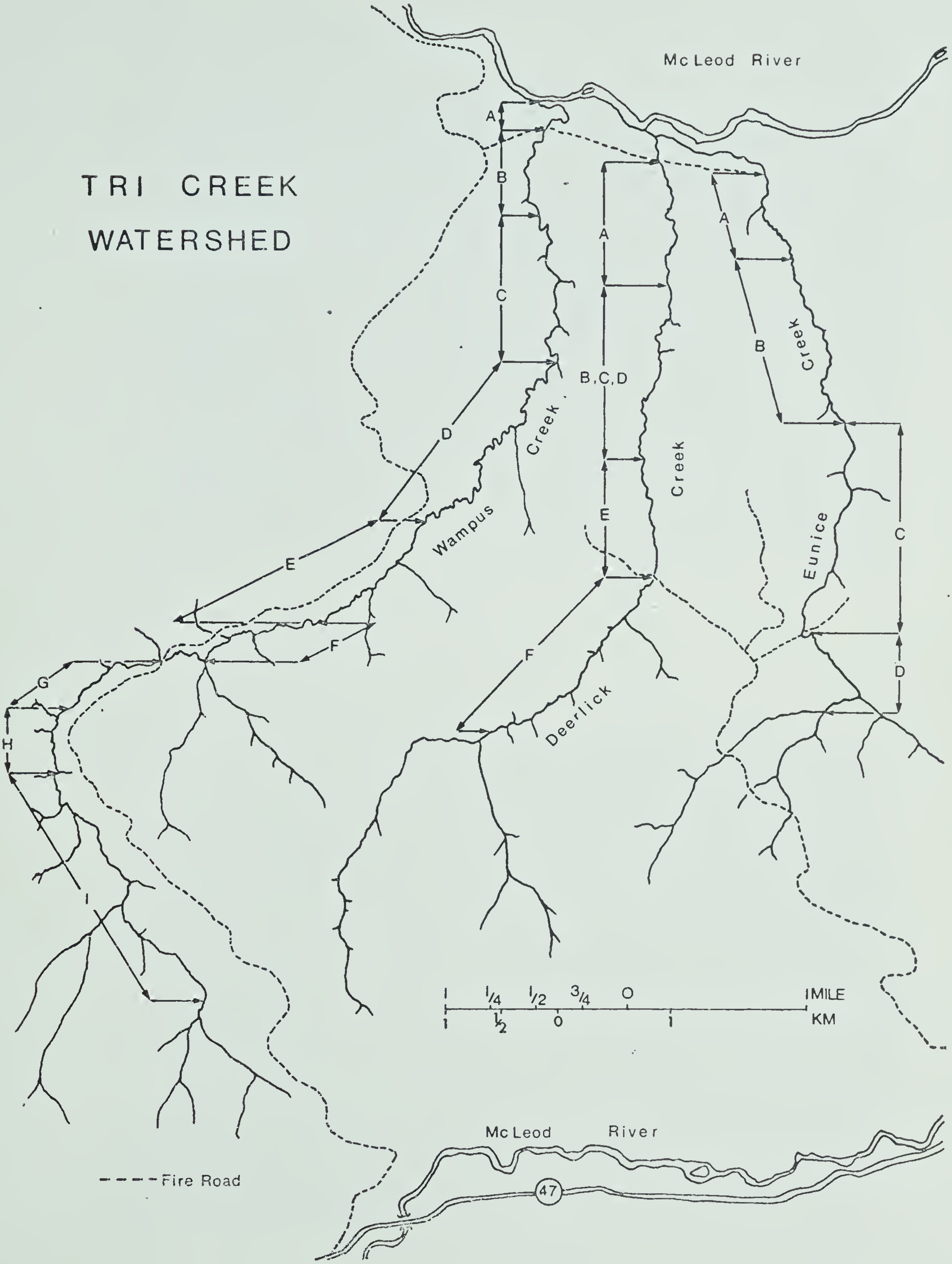


Figure 3. View of the Upper Wampus Creek basin; the Upper Wampus Creek bridge is located close to the right margin of the picture.

Figure 4. Meadow on Upper Wampus Creek; view downstream.

METHOD AND MATERIALS

Standing crop estimates of fish were made with a 425 V, 190 Watt D.C. backpack shocker and the simple mark and recapture method in adjoining sections in Wampus, Deerlick and a portion of Eunice Creek in the summer of 1970. The standard errors of population estimates were calculated from the formula

$$\text{S.E. } (\hat{N}) = \hat{N}\sqrt{\frac{(\hat{N} - m)(\hat{N} - c)}{mc(\hat{N} - 1)}}$$

where $\hat{N}$ = population estimate

m = total number of marked fish in the population

c = the number of fish in the sample.

Ninety-five percent confidence limits equal to two standard errors were calculated for the total stream estimates (Robson and Regier, 1968).

In 1969 the mark and recapture investigations were confined to a total of five study sections in Wampus and Deerlick Creeks. Eunice Creek and the remaining sections in each of the other streams were sampled with a view to obtaining at least a rough estimate of population sizes in each of the streams. This information was necessary for the planning of the investigation in 1970, which was to yield confirmation of or improvement on the previous year's estimate (Robson and Regier, 1964). During the routine sampling the fish's fork length was measured to the nearest millimeter; a scale sample was usually taken and the animal was marked by the removal of fins or combinations thereof before being returned to the water. In 1970 opercular straptags were tried but

their use was suspended after erosion of the gill epithelium became evident.

During the two summers a total of 1,189 rainbow trout (*Salmo gairdneri*, Richardson) was collected from the three tributaries to provide data on age, growth and fecundity. The 1970 McLeod River sample of 291 rainbow trout was taken with monofilament gill nets of various mesh sizes, the fish-shocker and rod and reel. It was assumed that sampling in this manner might have reduced the problem of size selectivity. Generally the fish were transported in an insulated container, partly filled with ice, and were processed on the day of capture. In addition to fork length and total length to the nearest millimeter, weight to the nearest tenth of a gram, and scales, the two otoliths were removed from each fish. Scales and otoliths were submerged in water and read separately with a binocular microscope and each fish was assigned to an age group. The mean lengths of fish in the various age groups were calculated and the average increase in mean length used as a measure of the annual growth of the populations. An age-length frequency table prepared from age information from otoliths (Table 1) was applied to estimates of numbers of fish in the various size classes to obtain the age structure of the August sample of trout from the tributaries.

Mature females, representing as much as possible a random sample of the population, were taken prior to the spawning period to provide data on fecundities of trout from the tributaries and the river.

Mean egg diameters were determined by noting the numbers of fresh, unfertilized eggs per 20 cm of a grooved, plastic ruler constructed for this purpose.

TABLE 1

AGE-LENGTH FREQUENCY TABLE PREPARED FROM 538 TROUT FROM WAMPUS AND DEERLICK CREEKS, AUGUST 1969, 1970

Fork length (cm)	Age in years									
	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+
1.0- 1.9	1									
2.0- 2.9	5									
3.0- 3.9	17	1								
4.0- 4.9	26	5								
5.0- 5.9	1	3								
6.0- 6.9		3	13	1						
7.0- 7.9		4	20	4						
8.0- 8.9			19	8						
9.0- 9.9			13	21						
10.0-10.9			14	38						
11.0-11.9			6	58						
12.0-12.9				33	2		1			
13.0-13.9				28	6	1	3			
14.0-14.9				9	9	2	4	1		
15.0-15.9				3	11	9	9	1		
16.0-16.9					4	15	12	1		
17.0-17.9					2	11	6	6		
18.0-18.9					1	8	11	5	1	1
19.0-19.9					1	5	3	3		
20.0-20.9						2	3	5	1	
21.0-21.9							1	5	4	
22.0-22.9						1	2	2		
23.0-23.9							1		1	
24.0-24.9							1			
Total	50	16	85	203	36	54	57	29	7	1
%	9.3	3.0	15.8	37.7	6.7	10.0	10.6	5.4	1.3	0.2

Sexing of the animals was accomplished by either gross or microscopic examination of the gonads. Age 0 fish were not included in the estimates of sex ratios. Confidence limits were calculated with the formula

$s = \sqrt{pq/n}$, where

s = standard error

p = proportion in which the attribute occurs in sample

q = $1 - p$, and

n = sample size (McFadden, 1961).

The stomach contents of a sample of 100 trout from the tributaries taken during the summer of 1969 were fixed in 10 percent formaldehyde and the results of the analysis were expressed in percent frequency of occurrence and in percent of the total number for each food item.

Thirty samples of spawning substrate in Wampus Creek were taken with a gravel sampler described by McNeil and Ahnell (1964) and analyzed by washing them through a series of 10 Tyler sieves with square mesh openings of 52.0, 25.0, 12.7, 6.4, 3.4, 1.7, 0.8, 0.4, 0.2 and 0.1 mm. The volume of each fraction was determined by water displacement and expressed as a percentage of the total sample.

RESULTS

STANDING CROP ESTIMATES

Wampus Creek

Table 2 presents the results of the mark and recapture experiments conducted in Wampus Creek in 1969 and 1970. An additional 357 trout, estimated on the basis of the average number of fish per 100-foot stream in sections F and G, resided in a 1,900-foot section which was not covered by the investigations. It was added to the pooled estimate of 4,831 resulting in a 1970 estimate for Wampus Creek of 5,188 trout. This total is equivalent to approximately 570 trout per mile (354 trout per kilometer) of stream.

On the assumption that the sampling gear selected against smaller fish (McFadden, 1961; Harvey and Davis, 1970), a separate estimate stratified by size classes was calculated for the stream (Table 3). This estimate of 5,315 fish was only 10 percent higher than the one arrived at by using the pooled mark and recapture data.

Deerlick Creek

Sampling in Deerlick Creek yielded the estimates listed in Table 4. Again the estimate for the stream stratified by size classes (Table 5) compared favorably with the one based on the pooled mark and recapture data and was found to be 9.2 percent higher than the latter estimate.

Eunice Creek

Unfortunately the number of trout in Eunice Creek, the "control

TABLE 2

STANDING STOCK ESTIMATES OF RAINBOW TROUT IN VARIOUS SECTIONS OF WAMPUS CREEK, 1969, 1970

Section	Date marked	Date recaptured	m	c	r*	$\hat{N}$ ± 1 S.E.	$\hat{N}$ ± 2 S.E.
A	5/19/70	5/28/70	6	44	3	88 ± 35	
B	5/16/69	8/17/69	54	88	13	365 ± 82	
B	8/26/70	8/27/70	227	187	97	438 ± 23	
C	6/10/70	7/5/70	82	106	20	435 ± 76	
D	6/11/70	7/8/70	158	69	9	1,211 ± 366	
E	6/12/70	7/8,9/70	160	230	28	1,314 ± 211	
F	7/19/69	8/26,27/69	95	83	13	606 ± 144	
F	8/16/70	8/22/70	267	250	130	513 ± 22	
G	8/18,19/69	8/21/69	181	168	26	1,170 ± 195	
G	8/17/70	8/23/70	395	417	191	862 ± 33	
H	6/23/70	7/1/70	250	188	72	653 ± 51	
I	6/29,30/70	7/2/70	157	212	50	666 ± 68	
A-I	Summer 1970		1,702	1,703	600	4,831 ± 127	4,831 ± 254

*Number of fish recaptured in sample.

TABLE 3

ESTIMATED NUMBER OF TROUT IN THE VARIOUS LENGTH GROUPS, WAMPUS CREEK, 1970

Fork length (cm)	m	c	r	$\hat{N} \pm 1$ S.E.
4.0- 6.9	26	21	5	109 ± 38
7.0- 7.9	66	86	9	631 ± 185
8.0- 8.9	127	147	29	644 ± 94
9.0- 9.9	194	192	59	631 ± 57
10.0-10.9	249	252	86	730 ± 52
11.0-11.9	264	257	93	730 ± 49
12.0-12.9	213	230	85	576 ± 38
13.0-13.9	151	164	79	313 ± 18
14.0-14.9	108	82	37	239 ± 24
15.0-15.9	77	82	29	218 ± 26
16.0-16.9	79	59	30	155 ± 16
17.0-17.9	55	46	26	97 ± 9
18.0-18.9	41	38	16	97 ± 14
19.0-19.9	22	25	9	61 ± 13
20.0-20.9	16	13	5	42 ± 12
21.0-23.9	14	9	3	42 ± 18
Total	1,702	1,703	600	5,315

TABLE 4

ESTIMATES OF NUMBERS OF TROUT IN THE VARIOUS STREAM SECTIONS,
DEERLICK CREEK, 1969, 1970

Section	Date marked	Date recaptured	m	c	r	$\hat{N} \pm 1$ S.E.	$\hat{N} \pm 2$ S.E.
A	6/24/70	6/26/70	42	58	6	406 ± 146	
B	6/23/70	6/24/70	96	90	43	201 ± 16	
C	7/25/70	8/3/70	80	77	27	228 ± 29	
D	7/26/70	8/5/70	117	80	29	323 ± 42	
E	8/2/70	8/6/70	151	151	66	345 ± 24	
F	7/26/69	8/23/69	27	63	7	243 ± 75	
F	8/9/70	8/16/70	150	141	78	271 ± 14	
A-F	Summer 1970		636	597	249	1,525 ± 57	1,525 ± 114

TABLE 5

ESTIMATED NUMBER OF TROUT IN THE VARIOUS
LENGTH GROUPS, DEERLICK CREEK, 1970

Fork length (cm)	m	c	r	$\hat{N} \pm 1$ S.E.
6.0- 8.9	39	34	6	221 ± 75
9.0- 9.9	100	83	25	332 ± 48
10.0-10.9	151	145	68	322 ± 21
11.0-11.9	132	120	46	344 ± 32
12.0-12.9	84	79	34	195 ± 20
13.0-13.9	35	33	17	68 ± 8
14.0-14.9	17	19	8	40 ± 8
15.0-15.9	13	12	6	26 ± 6
16.0-16.9	12	16	9	21 ± 2
17.0-17.9	18	11	7	28 ± 5
18.0-18.9	17	15	9	28 ± 4
19.0-19.9	8	14	8	14 ± 0
20.0-23.9	10	16	6	27 ± 6
Total	636	597	249	1,666

stream," was too low to warrant a mark and recapture investigation covering the entire creek. Investigations, therefore, were carried out in two sections and the remainder of the stream was sampled to provide an index of abundance of fish extending over most of the length of the stream.

The results of the experiments were as follows:

Section	Date marked	Date recaptured	m	c	r	$\hat{N} \pm 1$ S.E.
A	7/18/70	7/21/70	12	11	2	66 ± 38
D	6/28/70	7/10/70	29	18	5	104 ± 36

Thus, in 1969 and 1970 rainbow trout were found to be present in small numbers in areas A and D only, with the intermediate stretch being occupied by Dolly Varden (*Salvelinus malma*).

LINEAR DISTRIBUTION

The estimated numbers of trout in various portions of the tributary streams are detailed in Table 6.

Discussion

The mark and recapture method of estimating abundance of fish has a simple theoretical basis but in practice is subject to a number of complications (Allen, 1951). Difficulties arise when the investigation is conducted in an extended stretch of stream over an extended period of time, the method of capture is size selective, and the fish are territorial in habit. The various sources of experimental bias and the means of dealing

TABLE 6

LINEAR DISTRIBUTION OF RAINBOW TROUT IN WAMPUS DEERLICK AND EUNICE CREEKS, 1970

Stream	Section	Length in 1,000 feet	Length (m)	No. of fish per 100 feet (30.48 m)
Wampus Creek	A	1.7	518	5
	B	3.7	1,128	12
	C	4.4	1,341	10
	D	8.2	2,499	15
	E	6.5	1,981	20
	F	3.6	1,097	14
	G	3.7	1,128	23
	H	3.3	1,006	20
	I	10.5	3,200	6
Deerlick Creek	A	3.5	1,067	12
	B-D	7.0	2,134	10
	E	3.5	1,067	10
	F	5.0	1,524	5
Eunice Creek	A	4.0	1,219	2
	B	4.0	1,219	3

with them have been discussed by Ricker (1958) and more recently by Robson and Regier (1968).

In this investigation some precautions were taken in an attempt to reduce the experimental error: (a) the method of capturing fish with electricity, which is one of the least selective of all active fishing methods (Libosvarsky and Lelek, 1965), was employed; (b) marking fish by finclipping was chosen to minimize the problem of differential mortality of marked and unmarked fish, and regeneration of mutilated fins was considered unlikely in a short-term experiment of this type; (c) marked fish were released into the same stretch of stream in which they were caught in order to achieve a distribution of marked fish in proportion to the local abundance of unmarked fish along the watercourse.

The favorable agreement of estimates based on pooled mark and recapture data with those based on the numbers of fish in the various size classes is likely the result of a low variability in gear selectivity within the size range of fish comprising the dominant age classes. According to Ricker (1958) variations in vulnerability with size, though a common enough phenomenon, is not usually a serious problem.

The standing crop estimates for Wampus and Deerlick Creeks of 5,188 and 1,525 trout respectively should be regarded as minimal estimates. Although trout pervaded the two systems and were caught in the extreme headwaters and most of the small tributaries the numbers involved were considered to be relatively low. The table below juxtaposes the 1969 and 1970 estimates in three Wampus Creek sections and one Deerlick Creek section.

Stream	Section	1969 estimate ± 1 S.E.	1970 estimate ± 1 S.E.
Wampus	B	365 ± 82	438 ± 23
	F	606 ± 144	513 ± 22
	G	1,170 ± 195	862 ± 33
Deerlick	F	243 ± 75	271 ± 14

Comparison of the two estimates in the four stream sections suggests a low natural mortality of trout between August 1969 and August 1970 due primarily to a low predation pressure by Dolly Varden and burbot (*Lota lota*) in the small creeks.

AGE STRUCTURE

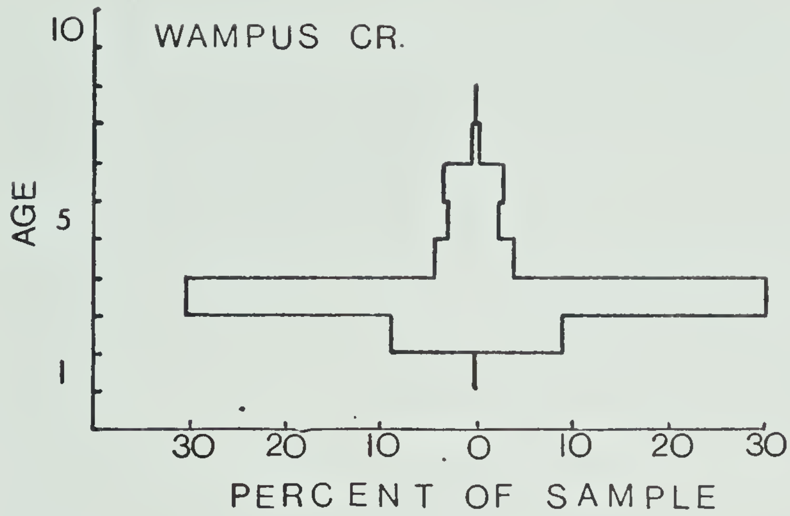
Population estimates stratified by size classes were made not only to compensate for any possible size selectivity of the sampling gear but also to obtain size and age specific vital statistics of the population. Since the mark and recapture experiments were conducted throughout the summer period the time lapse between release and recapture in some instances was long enough for detectable growth to have taken place and therefore there was no certain way of matching size classes of recaptured marked fish with size classes at the time of marking. This problem of maintaining the integrity of individual size classes was largely avoided by basing the age structures of the Wampus and Deerlick populations on August samples only and assuming growth between sampling dates in August to have been negligible.

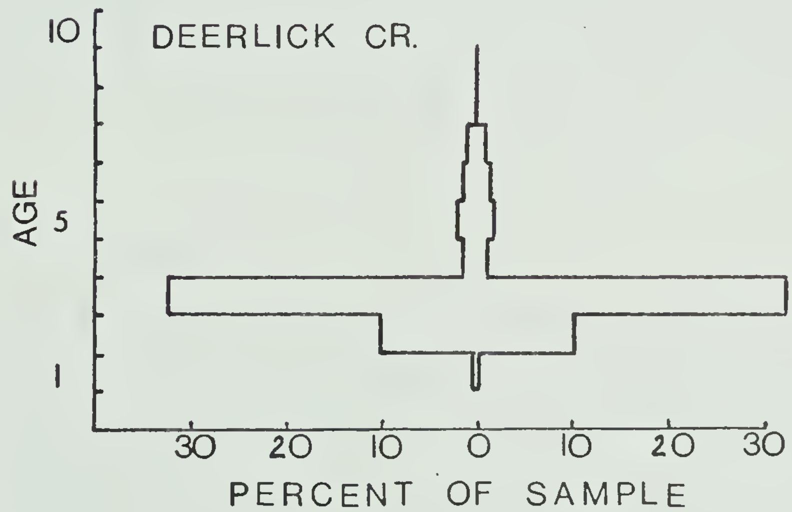
As expected the age analysis of scales from members of these dwarfed trout populations resident in the tributaries was a problem (Haugen, 1966). The agreement between scale- and otolith-ages of the same fish and between successive readings of the same scales was low. However the otolith picture was relatively clear and agreement between successive interpretations of otoliths was high. These results led to the decision to rely solely on otoliths for the purpose of age analysis of tributary trout. In the case of river trout agreement between scale- and otolith-ages was high and therefore both methods were used.

The age structures of samples from Wampus, Deerlick and the McLeod River are graphically presented in Figure 5. The dominance of the 1967 year classes in the three bodies of water is evident. The 1967 and 1968 year classes made up an estimated 60.8 and 17.9 percent respectively of samples from Wampus Creek, 65.1 and 20.4 percent of the Deerlick Creek catch, and 40.5 and 30.9 percent of the total number of fish taken from the McLeod River. In 1969 a freshet on June 6 resulting in widespread scouring of the spawning beds and a catastrophic flood on August 5 led to an apparent failure of that year class (Figures 6, 7 and 8).

Although recruitment of young to the Wampus Creek population was not measured collections of young of the year suggested only a moderate to low abundance of the 1970 year class as a result of a freshet on June 16. A post-flood examination of the heavily used spawning areas in the tailspills of pools indicated a high mortality of eggs as a result of scouring of the gravel substrate. Developing eggs were found only in "atypical" spawning sites such as in straight stretches of stream that may have been fed by groundwater.

Figure 5. Age structure of populations of rainbow trout from Wampus Creek, Deerlick Creek and the McLeod River, 1970.


WAMPUS CR.
AGE
10
5
1
30 20 10 0 10 20 30
PERCENT OF SAMPLE


DEERLICK CR.
AGE
10
5
1
30 20 10 0 10 20 30
PERCENT OF SAMPLE

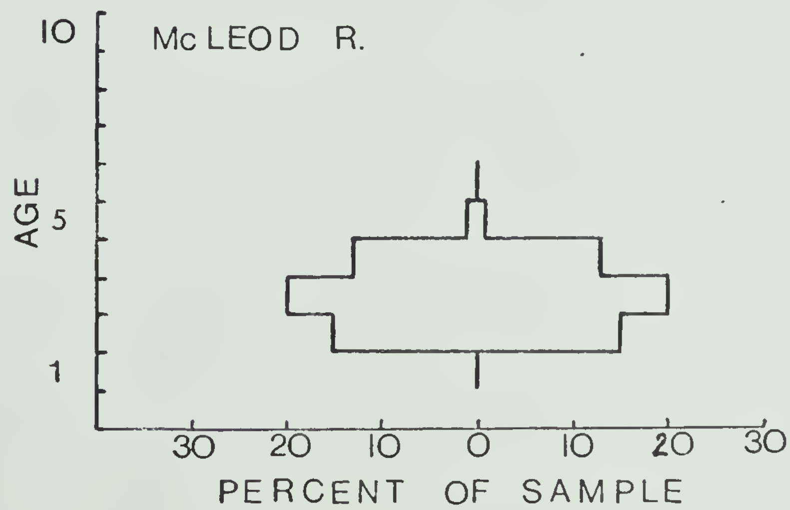
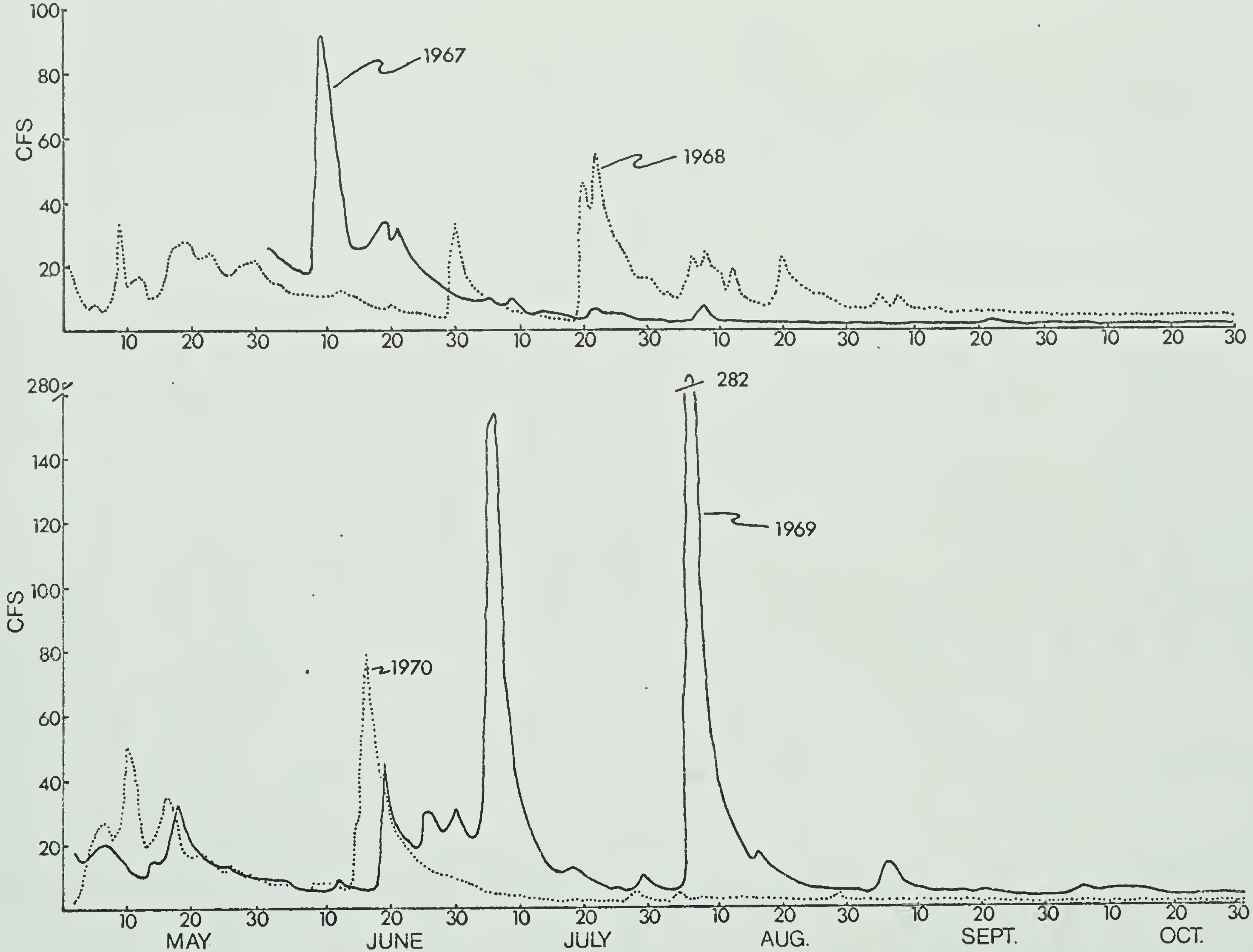

Mc LEOD R.
AGE
10
5
1
30 20 10 0 10 20 30
PERCENT OF SAMPLE

Figure 6. Downstream view of lower Wampus Creek in flood, August 5, 1969.

Figure 7. View of same stream section during "normal" flow, Nay, 1969.

Figure 8. Flow values of Wampus Creek, 1967-1970.



CFS
100
80
60
40
20
1967
1968
CFS
280
140
120
100
80
60
40
20
1970
282
1969
MAY
JUNE
JULY
AUG.
SEPT.
OCT.

High mortality among older age groups in the three populations may be related to the larger food and space requirements of larger fish which may exceed the available supply of these two resources particularly during the winter months.

A difference in the longevity of tributary and river trout is also apparent. The maximum ages attained by tributary and river trout were 9 and 6 respectively. Generally, slower growing fish tend to have a longer life span than faster growing fish.

GROWTH

Figure 9, showing two series of length-frequency histograms of Wampus and Deerlick Creek trout samples spanning the two summer periods, illustrates the general modal shift of the dominant 1967 year class with time. The variability of modal lengths in successive months is in part a reflection of the variability in growth rates in different portions of the creek. This phenomenon is shown more clearly in Figure 10, in which the length frequencies of trout in three sections of Wampus Creek sampled during August 1970 are compared. In sections F and G, separated by a 1,900-foot stream segment, the modal length of three-year-olds differed by 2 cm. The higher density of trout in section G may account for the difference in size of the age 3 fish.

The growth of the Wampus and Deerlick trout population presented in Figure 11 appears to be very similar, whereas the growth rate of trout from the river exceeds that of the tributary fish (Figure 12). Average fork lengths for trout of various ages are given in Table 7 and growth of age 0 trout is shown in Figure 13.

Figure 9. Length-frequency histograms of monthly samples of rainbow trout taken in Wampus and Deerlick Creeks during the summers of 1969 and 1970.

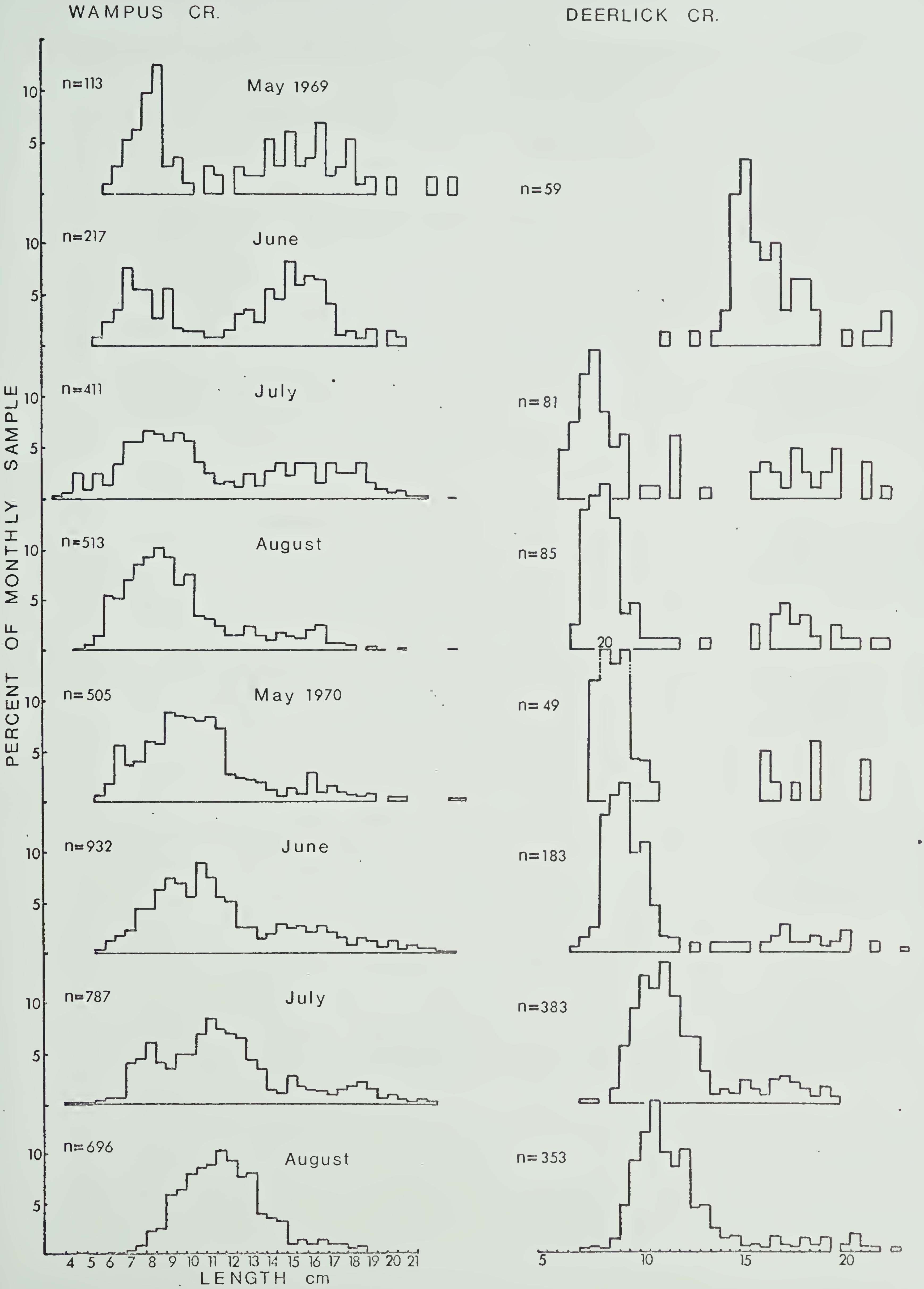

WAMPUS CR.
DEERLICK CR.
PERCENT OF MONTHLY SAMPLE
n=113
May 1969
n=59
n=217
June
n=411
July
n=81
n=513
August
n=85
n=505
May 1970
n=49
n=932
June
n=183
n=787
July
n=383
n=696
August
n=353
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
LENGTH cm
5 10 15 20

Figure 10. Length-frequency histograms of the August catches of rainbow trout in 3 sections of Wampus Creek, 1970.

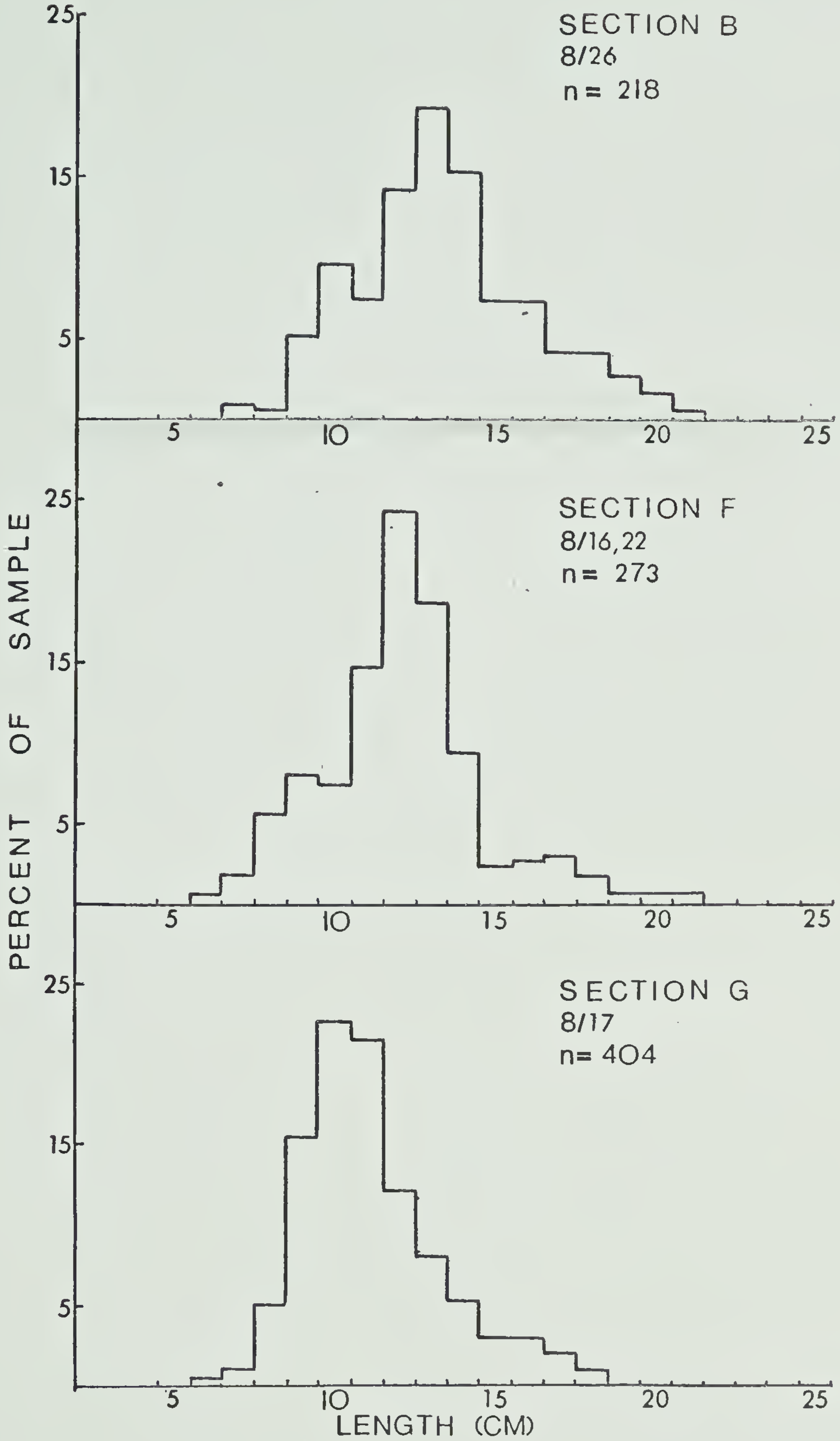
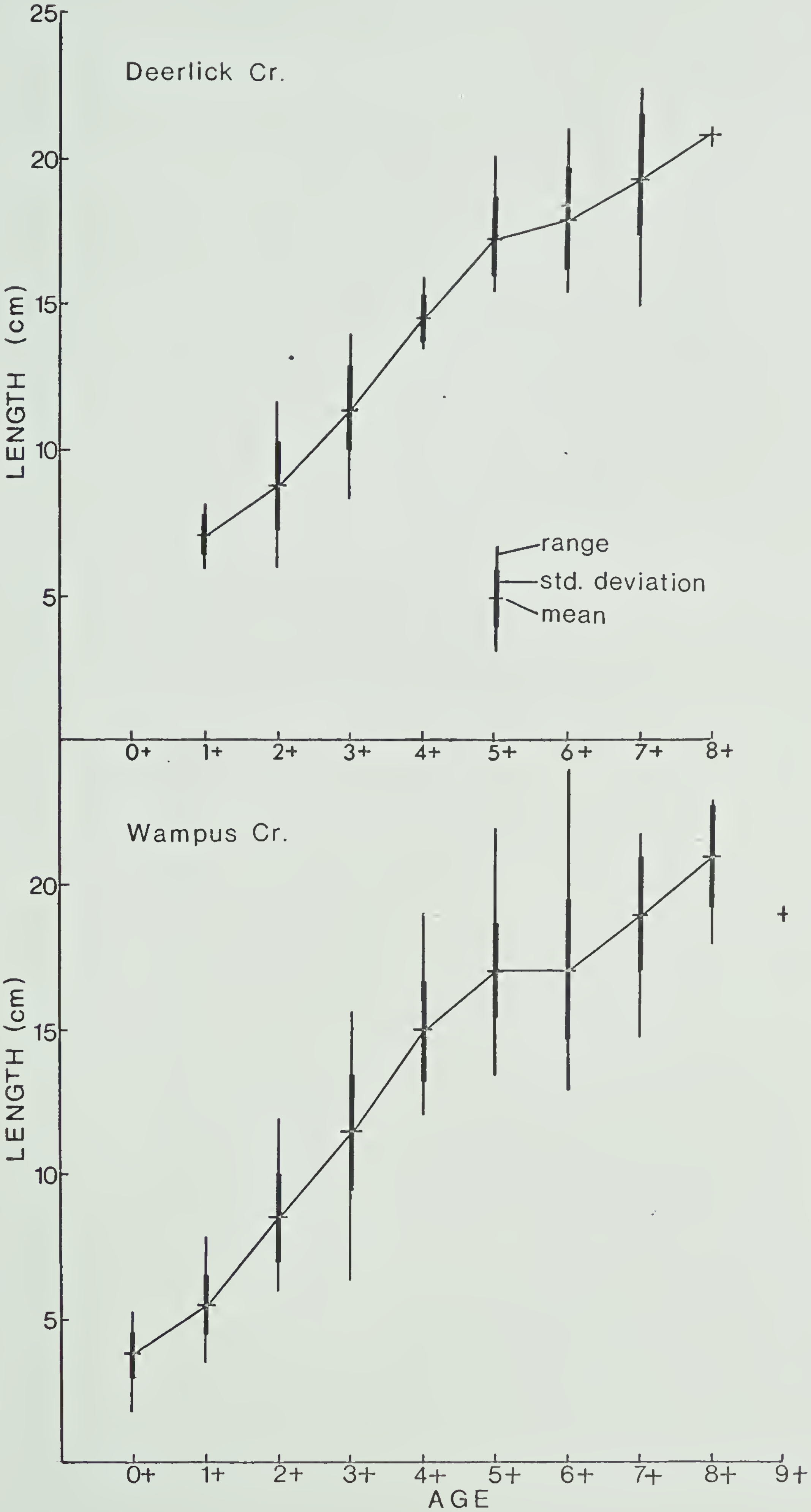
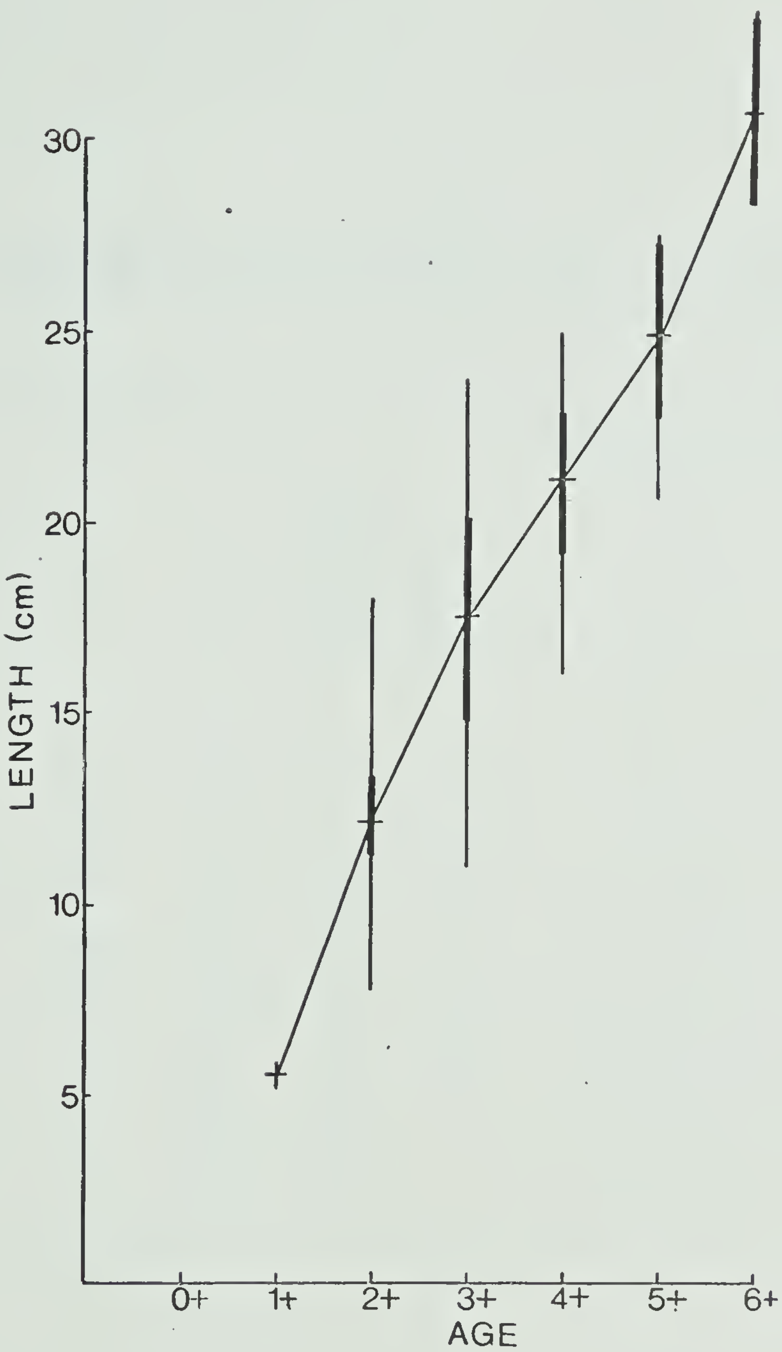

SECTION B
8/26
n= 218
SECTION F
8/16,22
n= 273
SECTION G
8/17
n= 404
PERCENT OF SAMPLE
LENGTH (CM)
25
15
5
5
10
15
20
25

Figure 11. Growth of rainbow trout in Wampus and Deerlick Creeks.



Deerlick Cr.
Wampus Cr.
LENGTH (cm)
LENGTH (cm)
25
20
15
10
5
20
15
10
5
range
std. deviation
mean
0+
1+
2+
3+
4+
5+
6+
7+
8+
0+
1+
2+
3+
4+
5+
6+
7+
8+
9+
AGE

Figure 12. Growth of trout in the McLeod River.



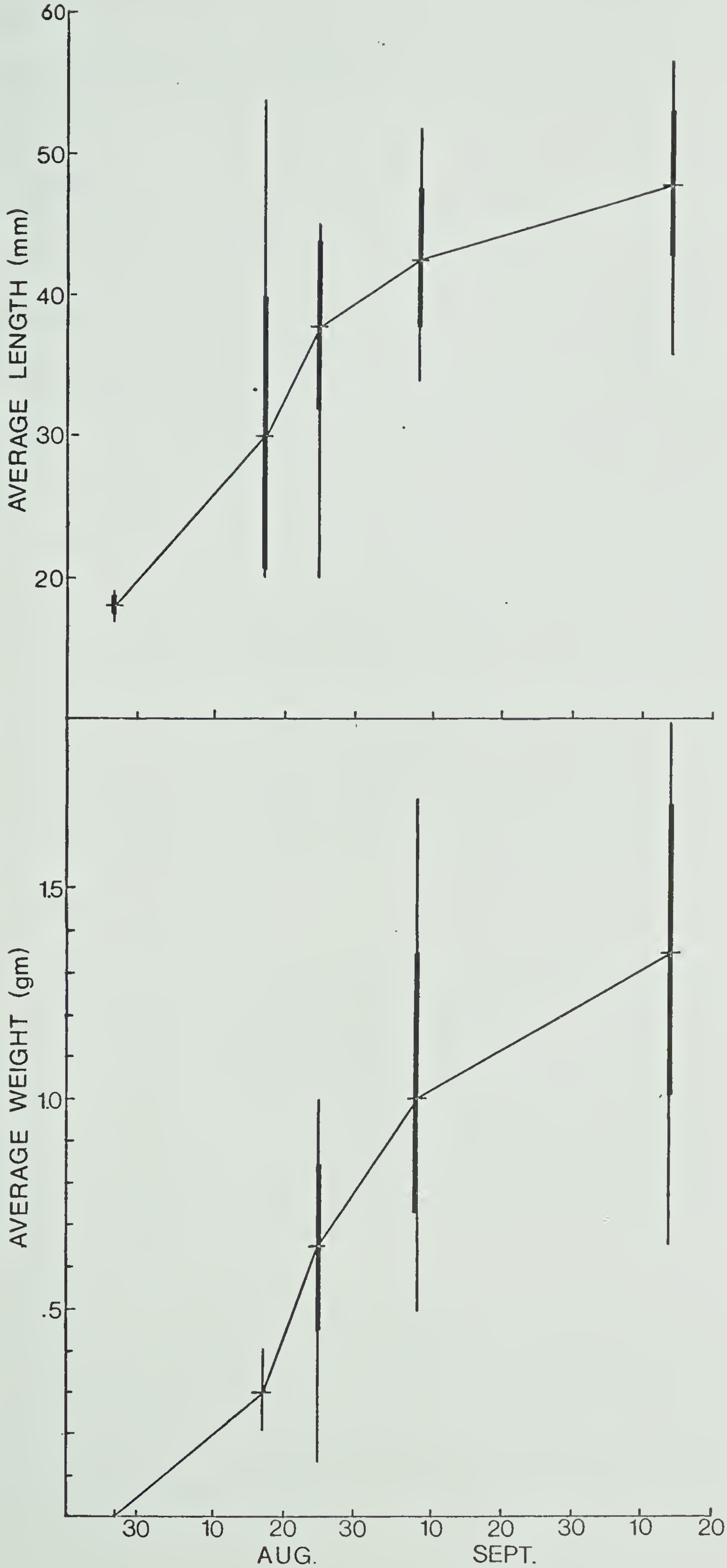
LENGTH (cm)
30
25
20
15
10
5
0+
1+
2+
3+
4+
5+
6+
AGE

TABLE 7

AVERAGE FORK LENGTH (CM) OF RAINBOW TROUT FROM WAMPUS CREEK (WA), DEERLICK CREEK (DEER) AND THE McLEOD RIVER (MC)

Age	No. of fish			Empirical length					
				Mean			Range		
group	Wa	Deer	Mc	Wa	Deer	Mc	Wa	Deer	Mc
0	50	-	-	3.8	-	-	1.8- 5.2	-	-
1	12	4	1	5.5	7.1	5.6	3.6- 7.8	6.1- 7.6	-
2	70	15	90	8.6	8.8	12.2	6.0-11.9	6.0-11.7	7.7-18.2
3	165	39	118	11.4	11.3	17.6	6.3-15.4	8.3-14.1	10.9-23.7
4	31	6	74	15.2	14.6	21.2	12.1-19.1	13.4-15.8	16.2-25.0
5	47	7	6	17.2	17.3	24.9	14.5-22.0	16.0-19.8	20.6-26.5
6	39	10	2	17.1	17.8	30.7	12.9-24.2	15.5-21.0	28.8-32.6
7	12	17	-	18.9	19.3	-	14.7-21.8	15.1-23.6	-
8	6	1	-	21.0	21.0	-	18.0-23.4	-	-

Figure 13. Growth in length and weight of age 0 rainbow trout in Wampus Creek, 1970.



60
50
40
30
20
AVERAGE LENGTH (mm)
1.5
1.0
.5
AVERAGE WEIGHT (gm)
30
10
20
30
10
20
30
10
20
AUG.
SEPT.

Discussion

The conclusion that the growth of trout from the McLeod River is greater than that of tributary trout is based on the assumptions that (a) the samples from the two areas are representative of the respective populations, and (b) the populations did not mix to a great extent. The first assumption cannot be justified for some age groups at present, and the second assumption, that we are dealing with essentially resident populations in the tributaries, is supported by the observation that only 0.2 percent of the 2,379 trout marked in the tributaries in 1970 were caught in the McLeod River. An upstream spawning movement of McLeod fish into Wampus Creek did take place but involved only 8 and 11 mature trout in 1969 and 1970 respectively. Spent adults were captured when leaving the creek but the fate of their progeny is not known. In 1969, movement of fish into and out of Wampus Creek was recorded with a two-way fish trap (Figure 14) and in 1970 with monofilament blocking nets set at the mouths of the tributaries.

The apparent difference in growth rates of tributary and river trout is most probably related to differences in their environments. The abundance of available food organisms, water temperatures, the length of the growing season, and the available space and population densities constitute the more important growth-controlling environmental features that may be involved here.

Differences in growth rates between various portions of the stream could be a result of competition by the trout for a limited food supply rather than a result of differences in the absolute abundance of food organisms along the water course. The number of fish per unit length of

Figure 14. Two-way fish trap blocking lower Wampus Creek in May and June, 1969.

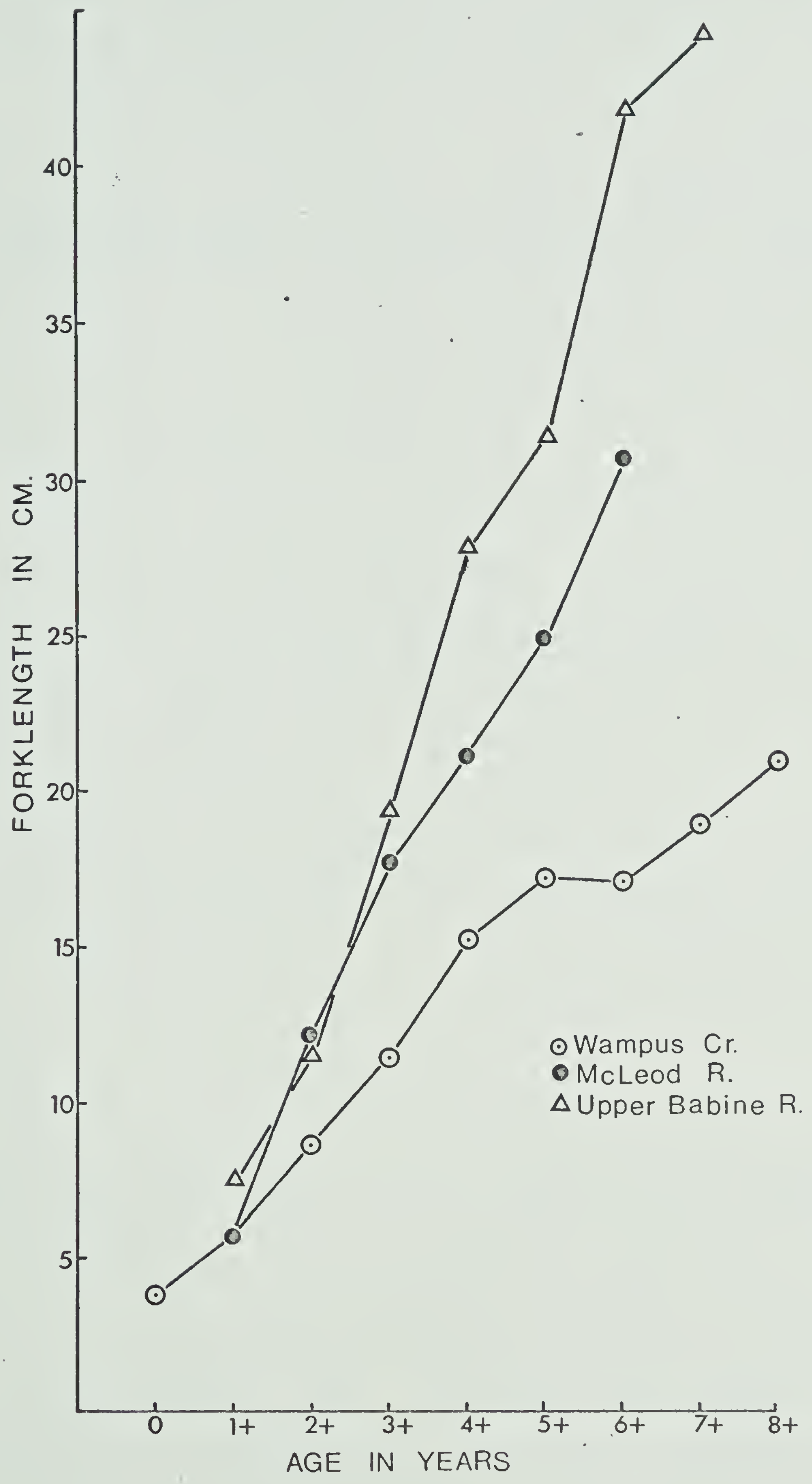
stream was lower in the section showing better growth than in the one in which growth appeared to be less. Supporting the contention that food is an important growth-limiting factor is the relatively low standing crop of trout food organisms (3.55 cc/m^2) in Wampus Creek (Zelt, 1968) which was lower than the 4.95 cc/m^2 reported by Tebo and Hassler (1961) for western North Carolina trout streams. Alm (1949) having investigated the reasons for the occurrence of stunted fish populations concludes that "the growth of different fish populations is entirely or, at any rate principally, dependent on the environment, being above all a question of nourishment" and that "apparently, hereditary bad growth in a certain population has not been observed."

In the summer of 1970 trout fry were growing rapidly, doubling their length in approximately one month, and continued their growth at a reduced rate until well into October. Conditions such as relatively high water temperatures and the absence of high flows were considered to have favored the growth of trout in the area at that time.

In Figure 16 the growth rates of rainbows from Wampus Creek and the McLeod River are compared to trout from the Upper Babine River (McCart, 1967). Possibly the faster growth rate of Babine River trout above age 3 results in part from a difference in the diet of the two populations. Twenty-eight percent of 106 stomachs of Babine trout contained sockeye fry and unidentified fish remains (McCart, 1967) whereas none of the 104 McLeod trout examined were found to be piscivorous. Other factors such as higher water temperatures and a longer growing season may also be important in contributing to the faster growth of Babine River rainbows.

Figure 15. Age 6+ rainbow trout from the McLeod River (upper picture) and Wampus Creek (lower photograph). Note absence of parr marks on the McLeod River fish. Parr marks are retained throughout the life of a tributary trout.

Figure 16. Growth of rainbow trout from Wampus Creek, the McLeod River and the Upper Babine River.



FORKLENGTH IN CM.
40
35
30
25
20
15
10
5
0
1+
2+
3+
4+
5+
6+
7+
8+
AGE IN YEARS
Wampus Cr.
McLeod R.
Upper Babine R.

FECUNDITY AND EGG DIAMETER

The egg content of tributary and McLeod River trout was linearly proportional to the length and total weight of the fish (Figures 17 to 20). The lengths of the fish and their egg contents are listed in Table 8. For the purpose of predicting fecundity, length was of somewhat greater value than weight in tributary fish with the reverse being true for McLeod River trout. The slopes of the regression lines of fecundity on length for river and tributary females were significantly different ($p < 0.001$). No attempt was made to fit a curve to the pooled fecundity data. The average fecundity of tributary and McLeod River females was 295 and 505 eggs per female respectively. In a sample of 33 females the egg content of the right ovary did not differ significantly from that of the left ovary. Figure 21 shows the relationship of average egg diameter and length for tributary trout. The relatively low correlation coefficient of 0.6 between the two variables indicates at best a very weak relationship. In the case of the McLeod River trout the correlation coefficient between the same variables was 0.22.

Discussion

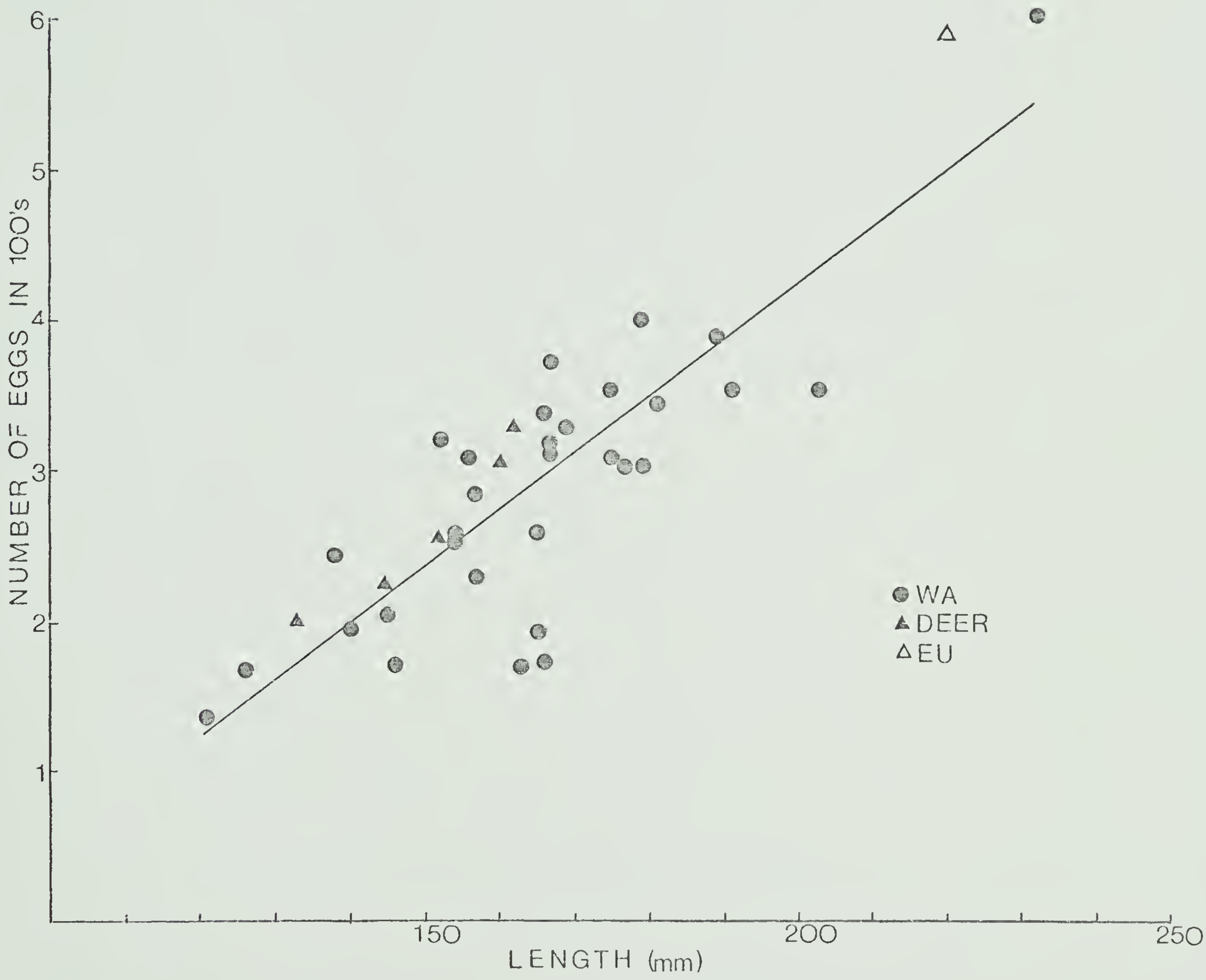
Since fecundity of the trout is affected by the rate of growth any factor that might change the food supply such as logging will also affect the fecundity. Feeding experiments with rainbow trout showed that food reduction led to a lower fecundity, probably through atresion of some of the eggs (Scott, 1962). Nikolskii (1969) suggests that fecundity is an adaptation to predation which determines the number of eggs needed to replace the stock, and food supply may limit the number of eggs which can be laid. Predation pressure in the creeks is very low and therefore

Figure 17. Fecundity-length relationship of rainbow trout from Wampus, Deerlick and Eunice Creeks, 1969, 1970.

$$y = -332.6 + 3.8x$$

$$r = 0.86$$

$$n = 38$$



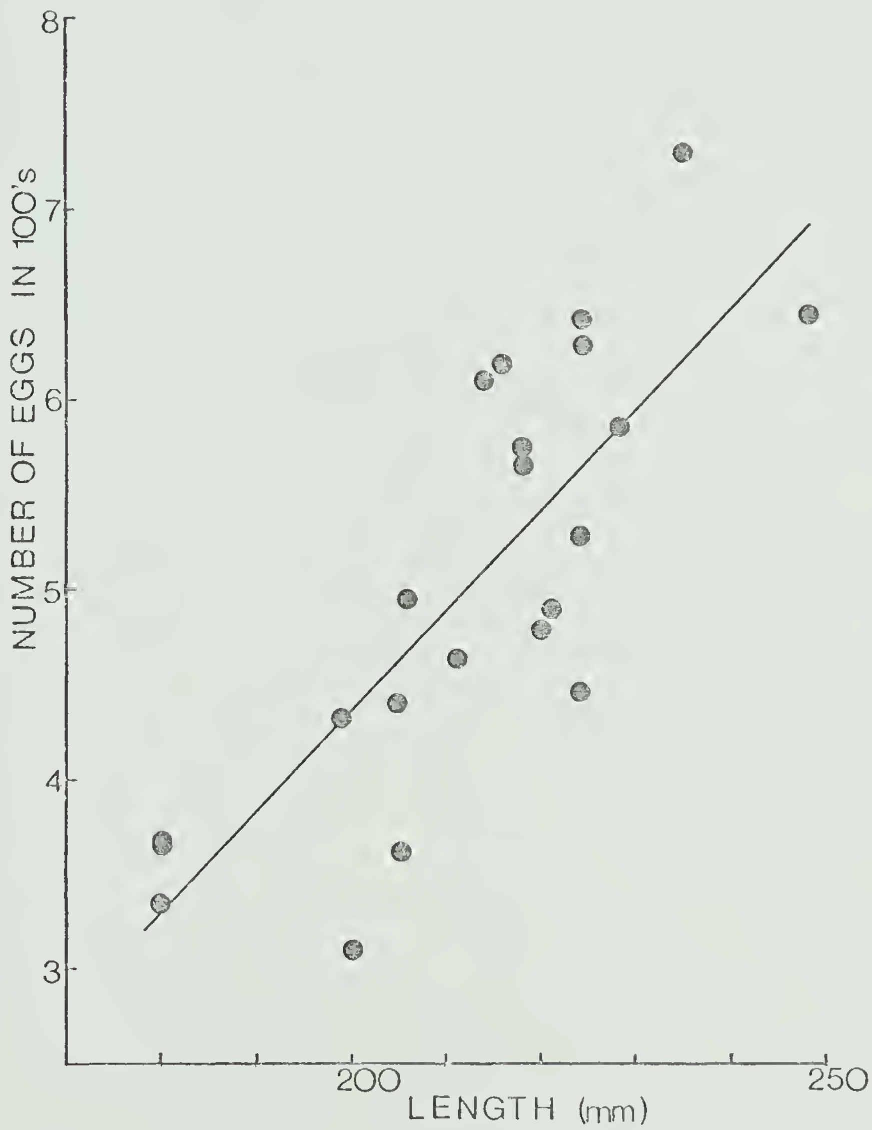
NUMBER OF EGGS IN 100's
6
5
4
3
2
1
150
200
250
LENGTH (mm)
WA
DEER
EU

Figure 18. Fecundity-length relationship of rainbow trout from the McLeod River, 1970.

$$y = -625.5 + 5.3x$$

$$r = 0.80$$

$$n = 22$$



8
7
6
5
4
3
NUMBER OF EGGS IN 100's
200
250
LENGTH (mm)

Figure 19. Fecundity-length relationship of trout from the tributaries and the River, 1969, 1970.

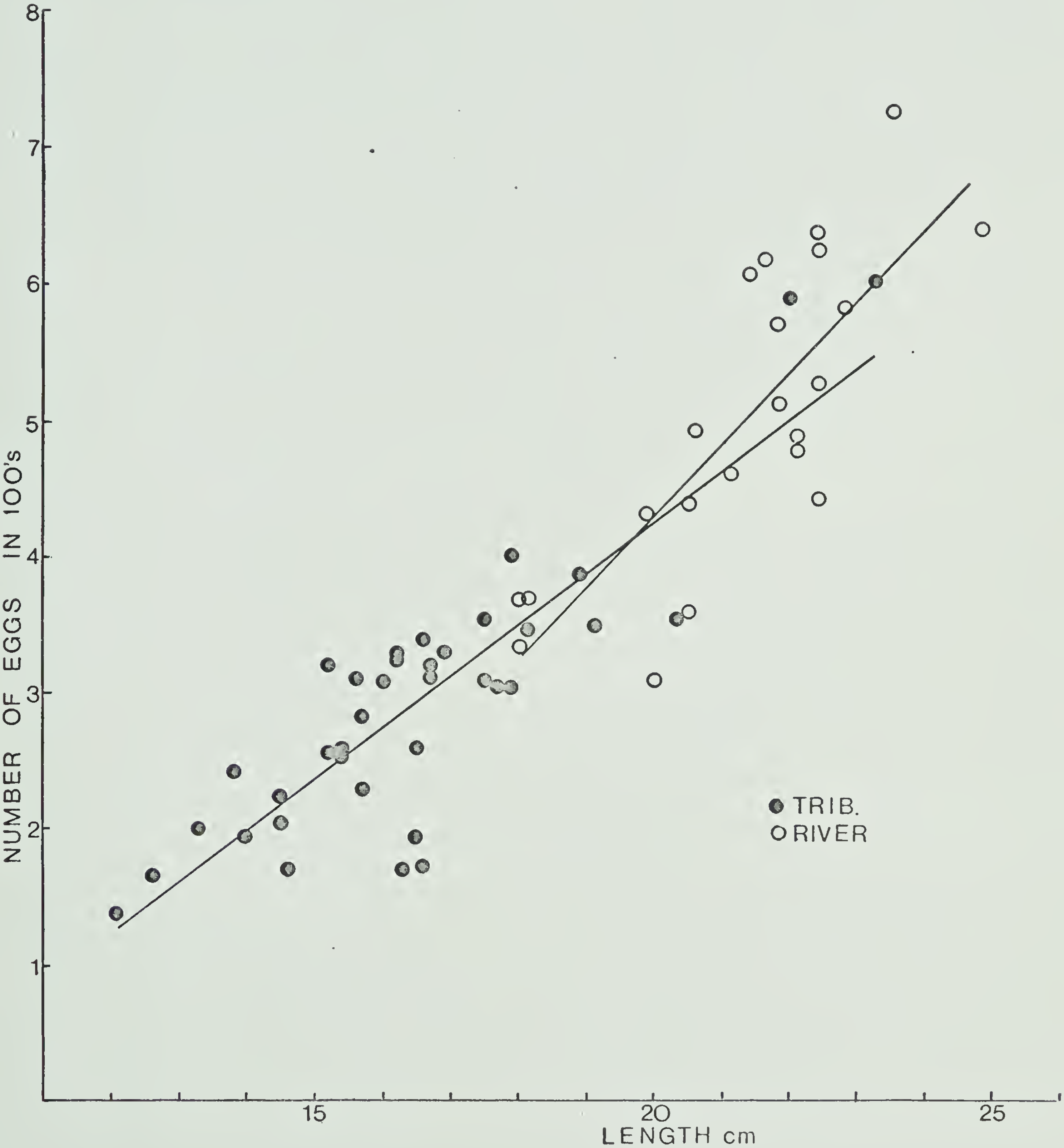

NUMBER OF EGGS IN 100's
8
7
6
5
4
3
2
1
15
20
25
LENGTH cm
TRIB.
RIVER

Figure 20. Fecundity-weight relationships of trout from the tributaries (●) and the McLeod River (o).

Tributaries: $y = 154.86 + 2.78x$

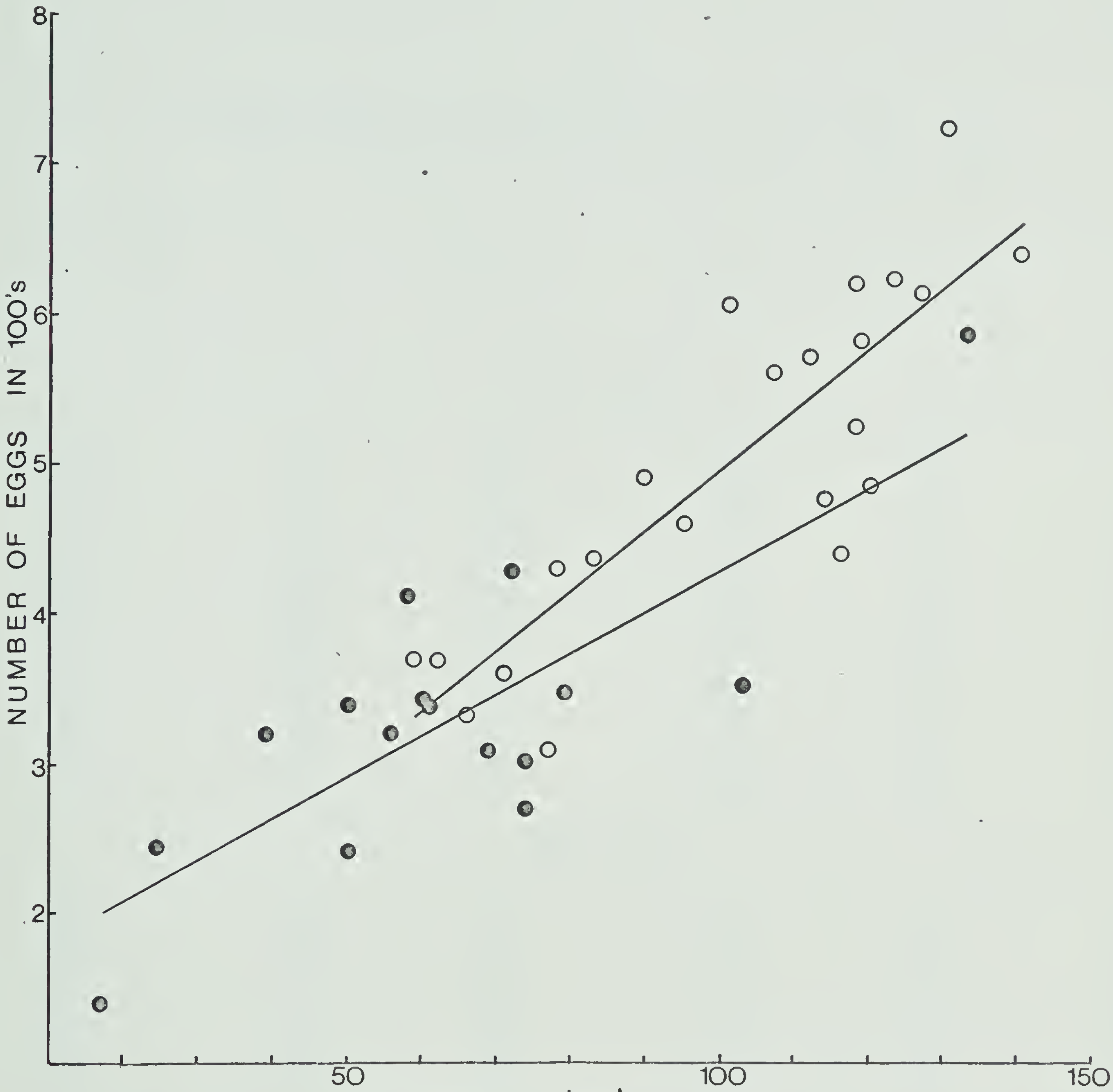
$r = 0.79$

$n = 16$

McLeod River: $y = 91.32 + 4.09x$

$r = 0.86$

$n = 22$



NUMBER OF EGGS IN 100's
8
7
6
5
4
3
2
50
100
150
WEIGHT (gm)

TABLE 8

FORK LENGTHS AND EGG NUMBERS FOR RAINBOW TROUT FROM THE TRIBUTARIES AND THE McLEOD RIVER: 1969, 1970

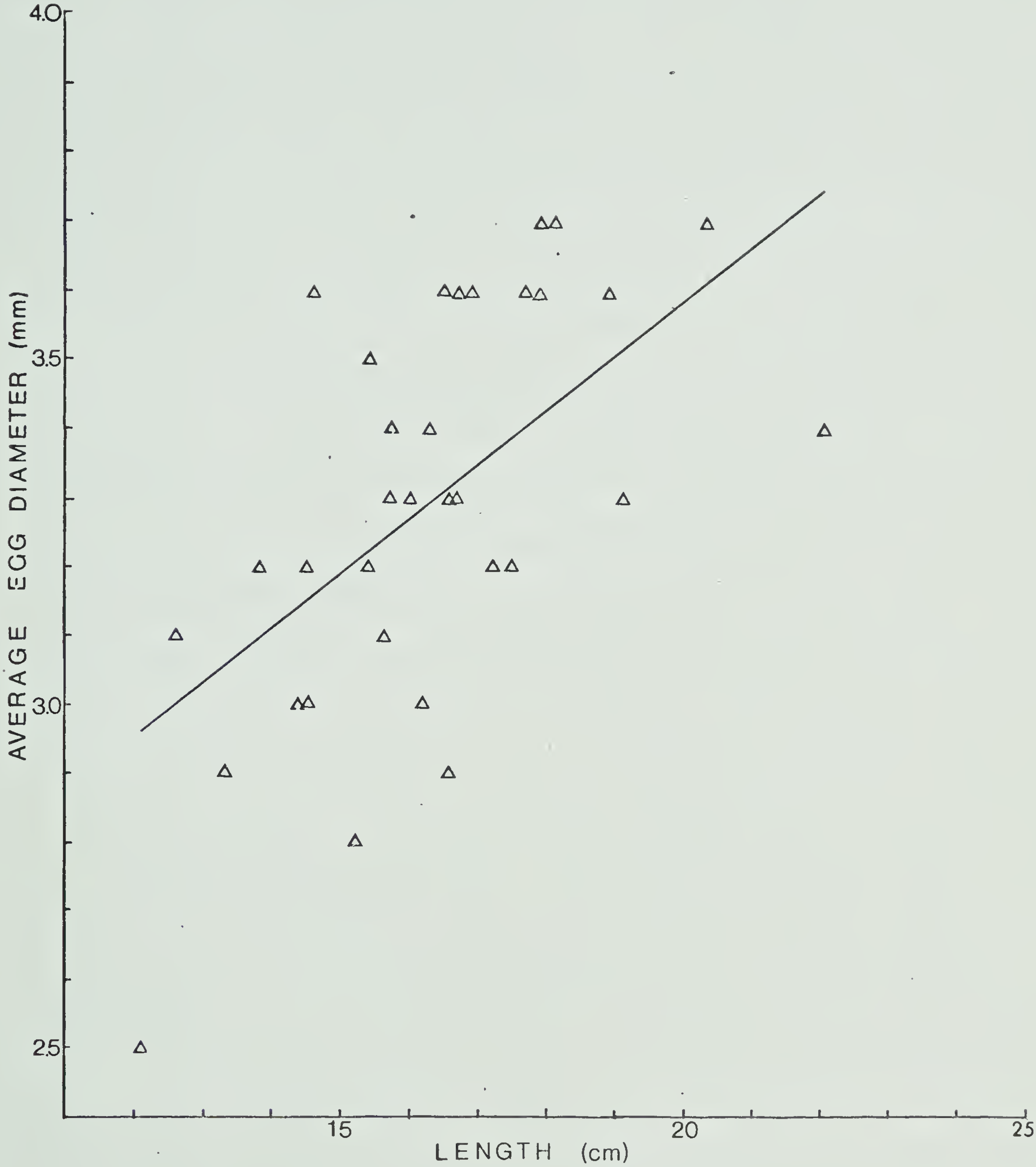
F.L. (mm)	No.	F.L. (mm)	No.	F.L. (mm)	No.
		Tributaries			
121	138	157	286	167	374
126	167	157	229	175	310
133	201	160	308	175	355
138	245	162	325	177	305
140	194	162	328	179	306
145	205	163	169	179	401
145	226	165	192	181	347
152	256	165	260	189	390
151	322	166	172	191	351
154	260	166	339	203	356
154	252	167	313	220	592
156	310	167	318	232	606
		McLeod River			
180	336	211	463	224	444
180	369	214	609	224	529
180	370	216	619	224	628
200	311	218	564	224	642
205	362	218	575	228	586
205	441	221	479	235	730
206	494	221	490	248	644

Figure 21. Relationship between average egg diameter and length of trout from the tributaries; 1969, 1970.

$$y = 1.99 + 0.008x$$

$$r = 0.6$$

$$n = 34$$


4.0
3.5
3.0
2.5
AVERAGE EGG DIAMETER (mm)
15
20
25
LENGTH (cm)

a relatively small number of eggs is sufficient to perpetuate the stock. Extrapensatory mortality factors such as scouring of spawning beds appear to be of greater importance than predation in determining recruitment.

Local fecundity differences have been reported for Atlantic herring (Baxter, 1963), plaice (Bagenal, 1966) and sockeye salmon (Aro and Broadbent, 1950). It is not known to what degree these differences are genetic but Bagenal could explain all local fecundity differences in plaice in terms of adaptation of the fish to their specific environment, the main factor being food supply. Egg diameter, by determining the size of the fry at hatching (Dahl, 1918), may have a bearing on its chances for survival. Pope (1961) found a statistically significant positive correlation between the mean egg diameter and fish size in Atlantic salmon from six Scottish rivers, and Singley (1957) demonstrated that less fecund bullheads (*Cottus gobio*) laid smaller eggs than the more fecund individuals. However, these findings are contrasted by observations on herring that showed the less fecund individuals having larger eggs than the ones with high fecundities (Parrish and Saville, 1965). In the present case the variability of egg size within a length group is such as to make the statistical association weak. The problem of variable egg size in tributary fish, however, is interesting enough to warrant further attention.

SEX RATIO

The percentage of females in samples of trout taken from the three creeks and the river and the percentage of females in the various length classes of Wampus Creek fish are detailed in Tables 9 and 10.

TABLE 9

PERCENTAGE OF FEMALE RAINBOW TROUT IN SAMPLES TAKEN FROM THE THREE TRIBUTARIES AND THE McLEOD RIVER IN 1969 AND 1970

	Wampus Cr.	Deerlick Cr.	Eunice Cr.	McLeod R.
n	527	151	89	288
Percentage females	43.6	51.6	44.9	55.2
95% confid. 1's	39.6-47.6	43.6-59.6	43.9-54.9	47.2-63.2

TABLE 10

PERCENTAGE OF FEMALE RAINBOW TROUT OF THE VARIOUS LENGTHS FOR WAMPUS CREEK TROUT

Fork length (cm)	n	Percent of total	Percent females
6.0- 6.9	10	1.9	50.0
7.0- 7.9	15	2.9	53.3
8.0- 8.9	14	2.7	64.3
9.0- 9.9	30	5.8	60.0
10.0-10.9	48	9.2	39.6
11.0-11.9	55	10.6	45.4
12.0-12.9	42	8.1	42.8
13.0-13.9	46	8.8	39.1
14.0-14.9	51	9.8	43.1
15.0-15.9	55	10.6	58.2
16.0-16.9	55	10.6	45.4
17.0-17.9	31	6.0	61.3
18.0-18.9	24	4.6	37.5
19.0-19.9	16	3.1	12.5
20.0-20.9	16	3.1	6.2
21.0-21.9	5	1.0	0.0
22.0-22.9	2	0.4	50.0
23.0-23.9	4	0.8	75.0
24.0-24.9	1	0.2	0.0
	520	100.0	

LENGTH-WEIGHT RELATIONSHIPS

The length-weight relationships based on data from 443 Wampus, 141 Deerlick, 76 Eunice Creek and 278 McLeod River trout are expressed as the average weight of fish in each centimeter class and are presented in the form of four equations as follows:

Wampus Creek:	$\log wt = -1.86 + 2.93 \log L$
Deerlick Creek:	$\log wt = -1.91 + 3.0 \log L$
Eunice Creek:	$\log wt = -1.85 + 2.91 \log L$
McLeod River:	$\log wt = -1.78 + 2.84 \log L$

Although trout from the river grow faster than tributary trout, their length-weight relationships are similar (Figure 22).

LIFE HISTORY OF RAINBOW TROUT IN WAMPUS CREEK

Male and female rainbow trout in the river and the tributaries mature at ages 3 and 4 respectively. In 1970 the spawning period, whose beginning roughly coincided with an 8° C rise in water temperature over a one-week period, fell on the first 10 days of June (Figures 23 and 24) with the peak having occurred on June 4. In 1969 the rise in creek temperature occurred earlier than in 1970 with a consequent shift in the spawning period (Figures 23 and 25). Not all spawning activity, however, was confined to a discrete period but isolated incidences of spawning in the tributaries were observed as late as July 2. The average redd residence of females determined from the observation of 7 marked trout was 0.9 days. Generally the preferred spawning localities were characterized by relatively swift current, loose gravel of hazelnut size and smaller and convex bottom contours (Figures 26 and 27). The latter feature is

Figure 22. Length-weight relationship for Wampus Creek and McLeod River trout; 1969, 1970.

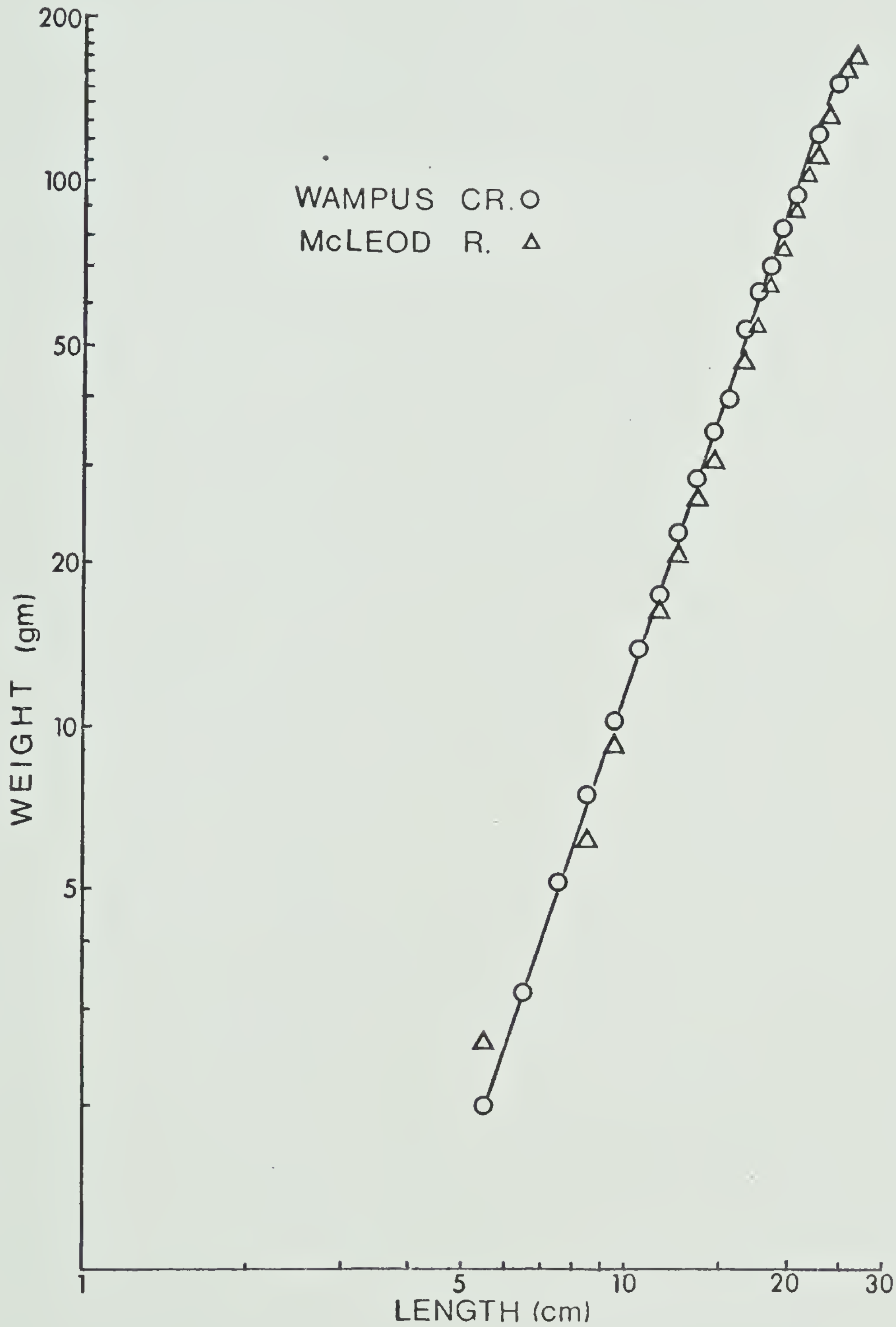
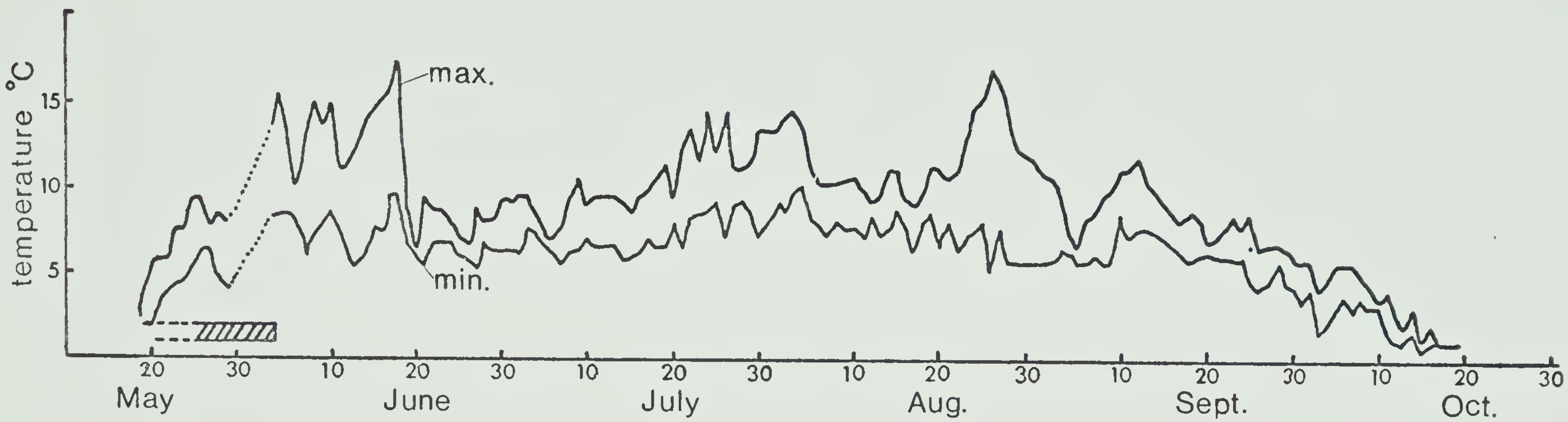
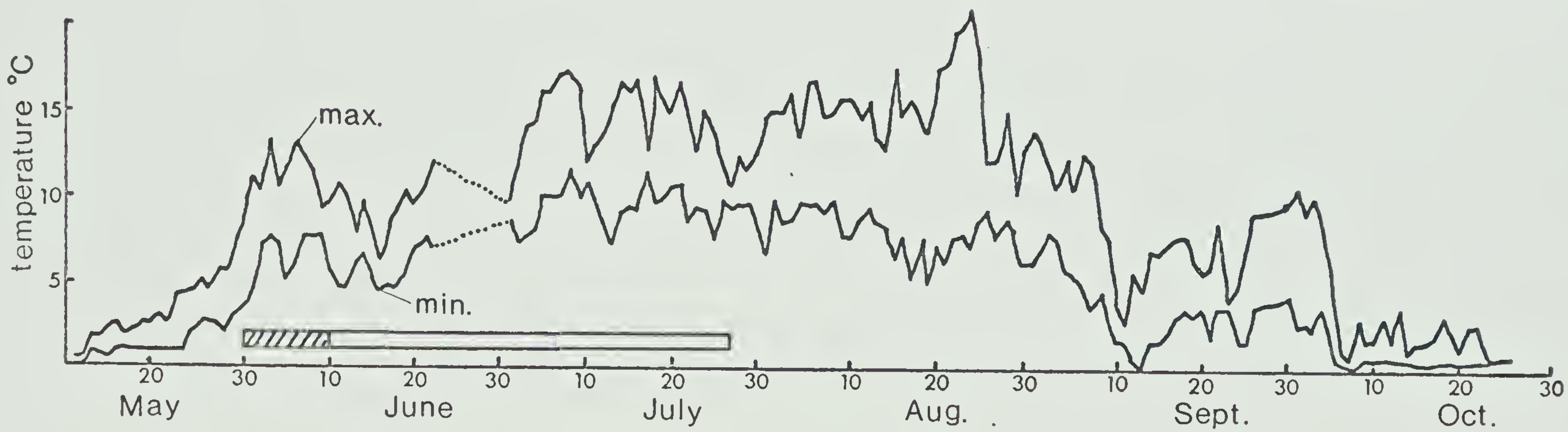

WAMPUS CR. O
McLEOD R. △
WEIGHT (gm)
200
100
50
20
10
5
LENGTH (cm)
1
5
10
20
30

Figure 23. Wampus Creek temperatures recorded in 1969 and 1970. Cross-hatched bar represents duration of spawning period; open bar designates length of incubation period in 1970.

Wampus Cr., 1969

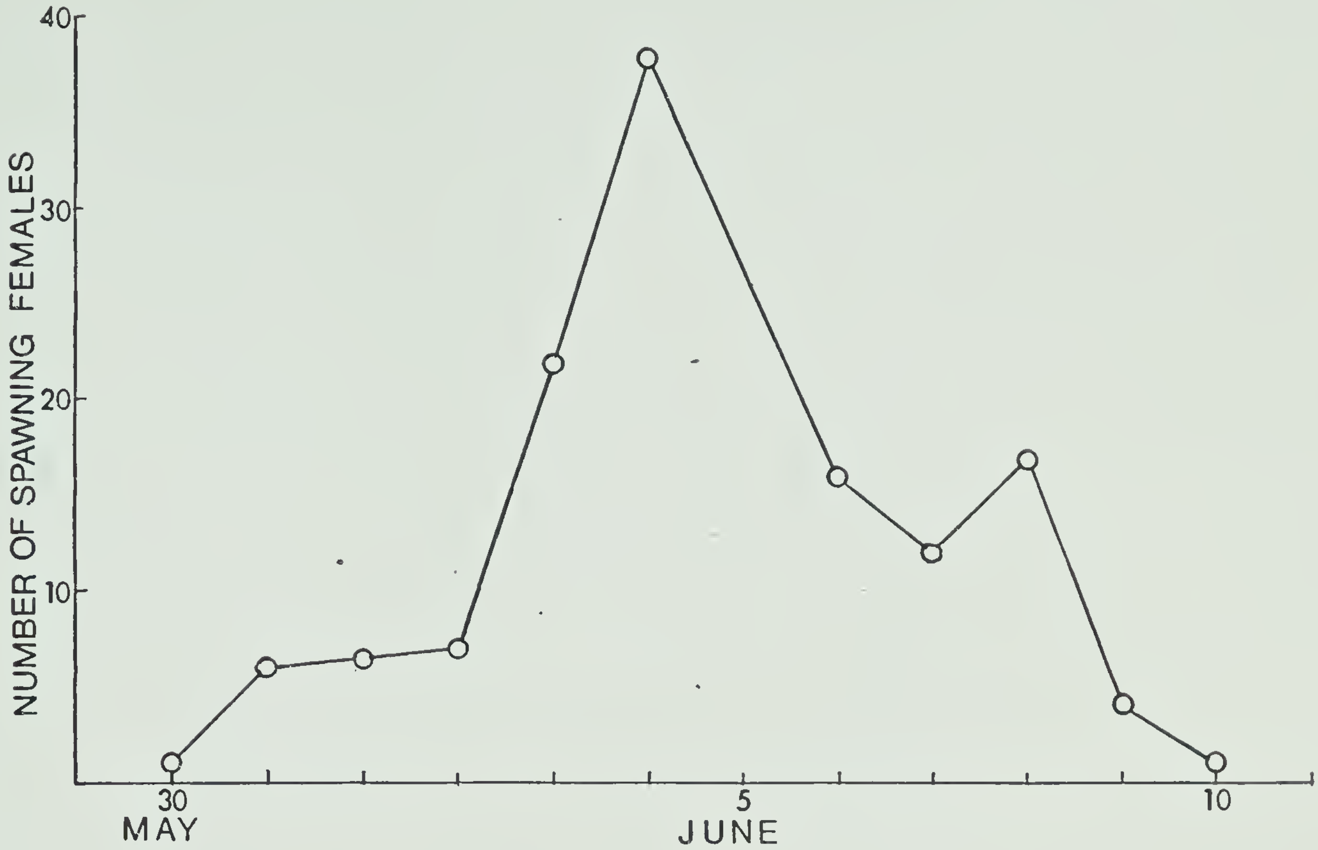




Wampus Cr. . 1970

Figure 24. Graph showing daily changes in abundance of spawning females in sections F and G, Wampus Creek, 1970.

Figure 25. Graph showing percentages of spent, spawning and mature fish in samples of rainbow trout taken in the period from May 25 to June 5, 1969, in Wampus Creek.


NUMBER OF SPAWNING FEMALES
40
30
20
10
30
MAY
5
JUNE
10

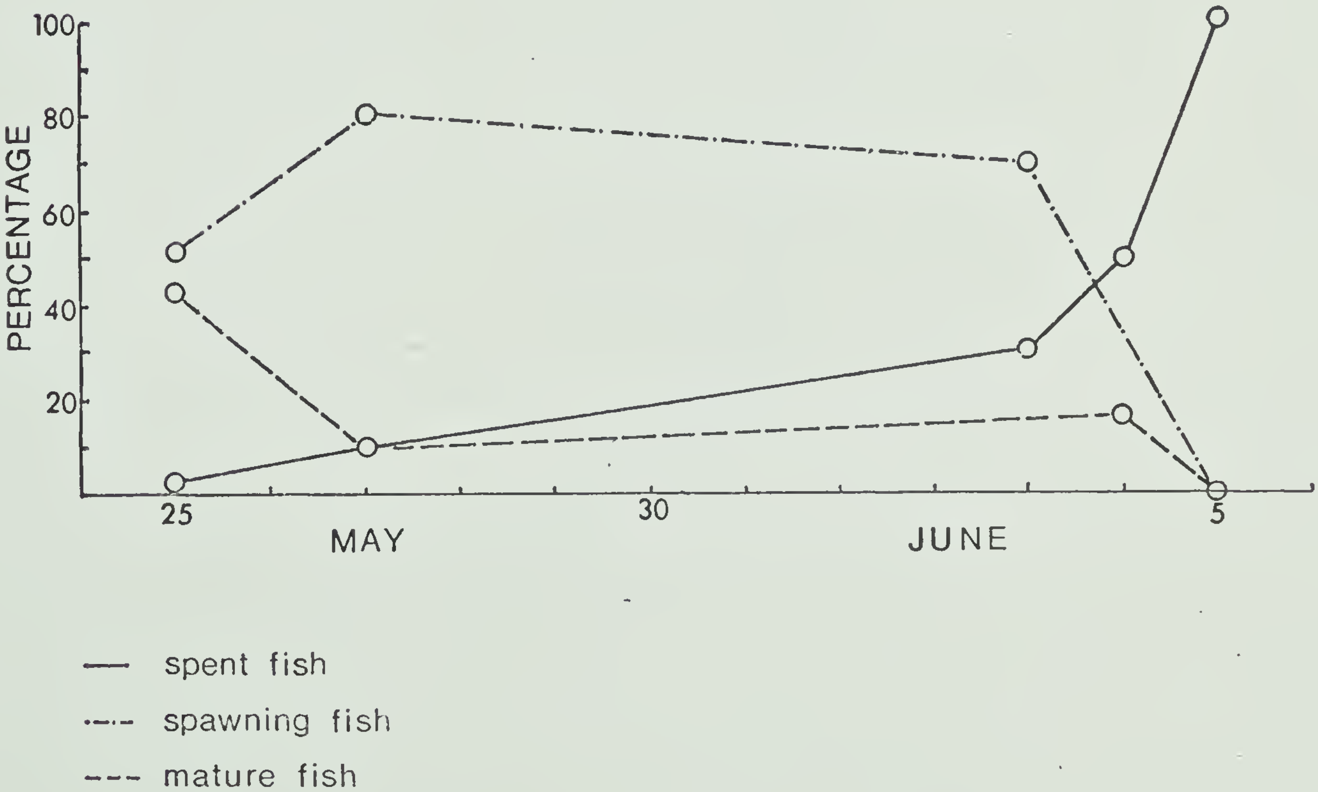

PERCENTAGE
100
80
60
40
20
25
MAY
30
JUNE
5
spent fish
spawning fish
mature fish

Figure 26. Composition of 15 samples of spawning gravel from section G of Wampus Creek, 1969, 1970.

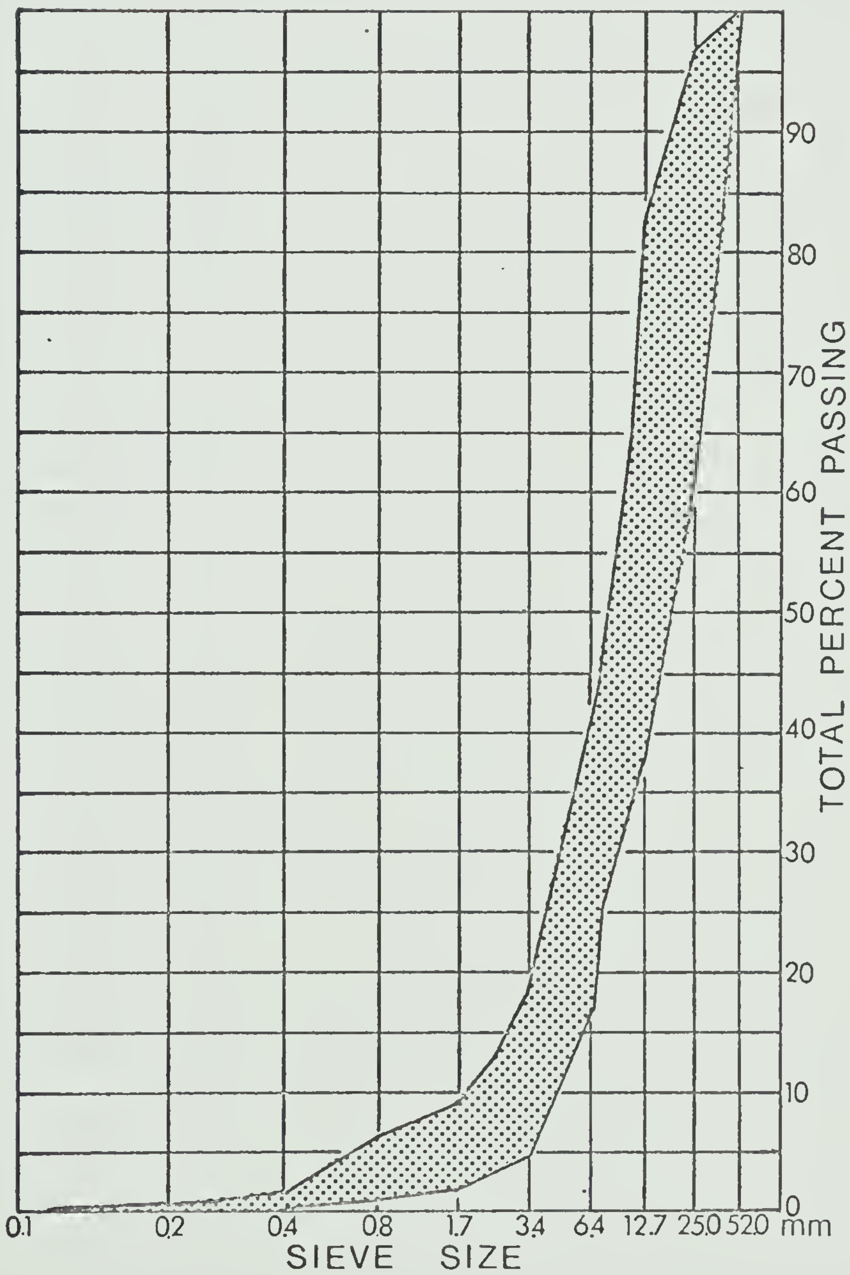
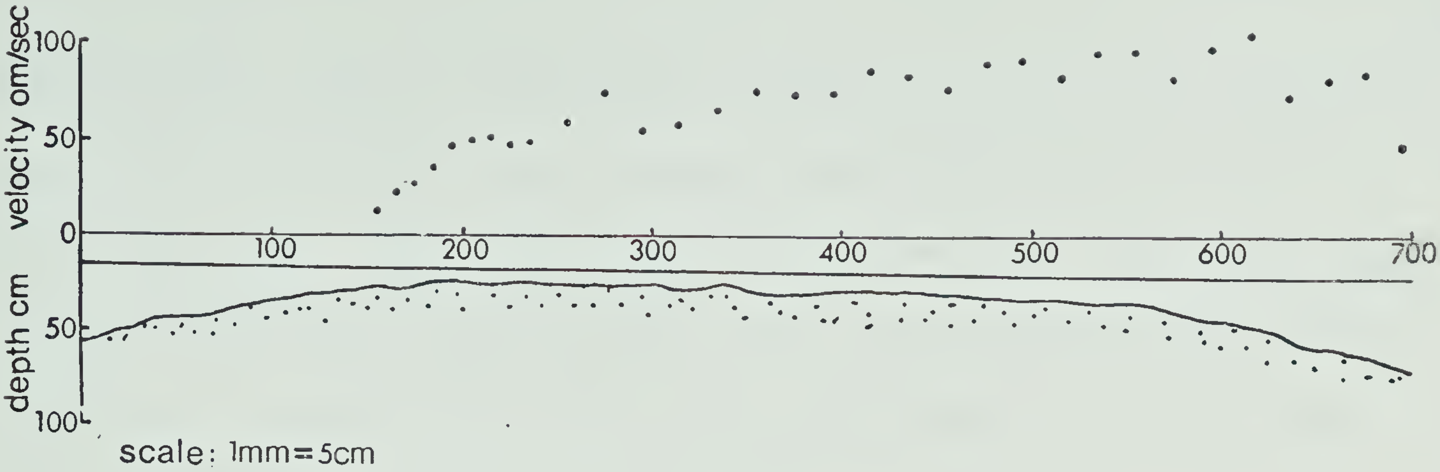
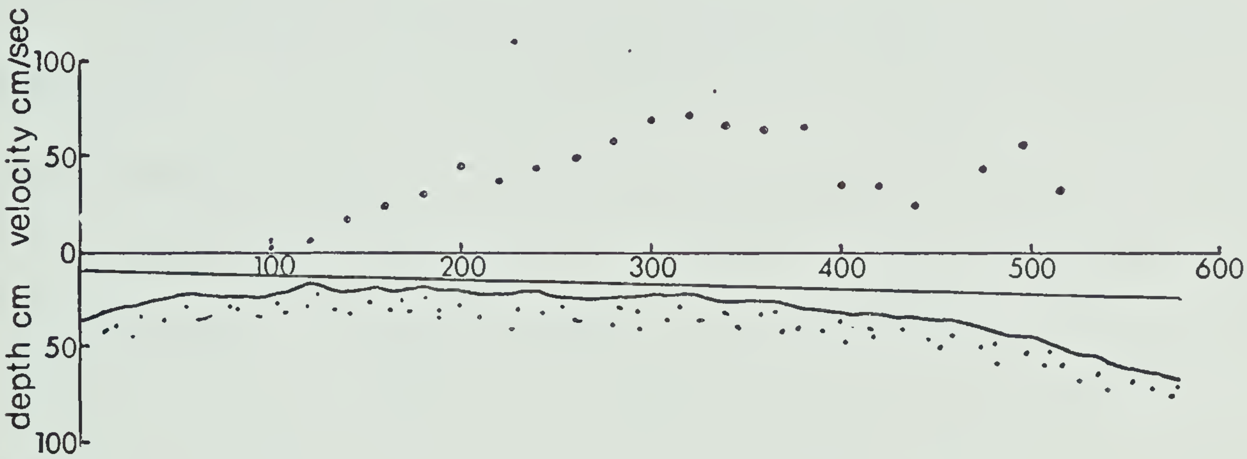
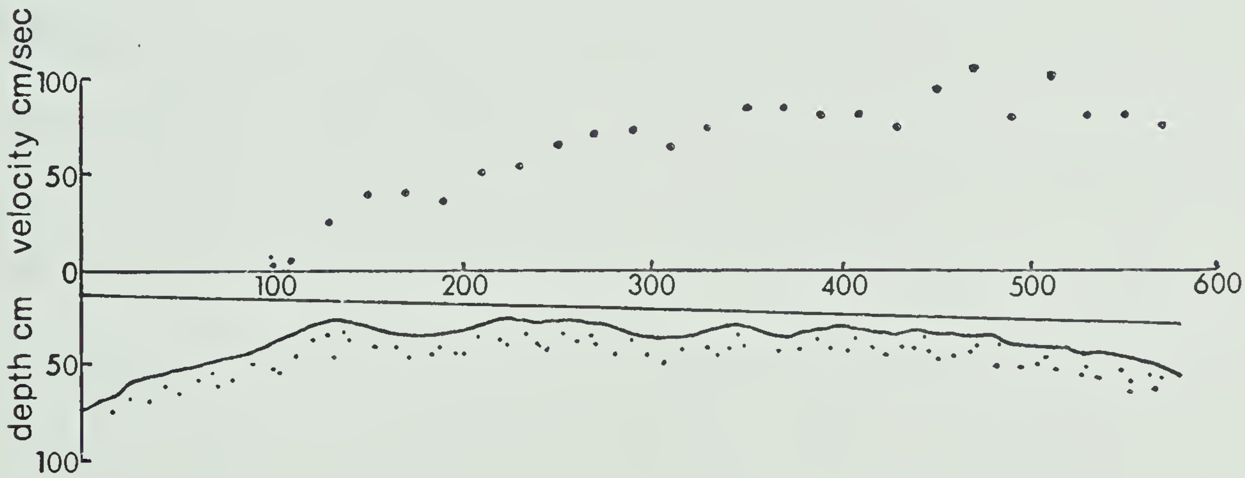
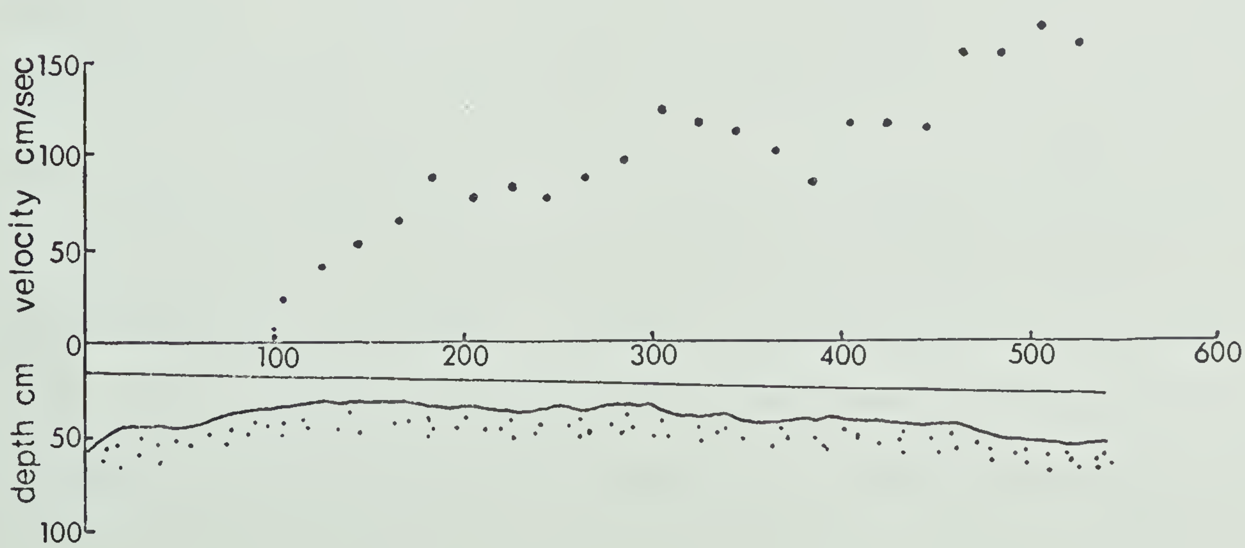

90
80
70
60
50
40
30
20
10
0
TOTAL PERCENT PASSING
0.1
0.2
0.4
0.8
1.7
3.4
6.4
12.7
25.0
52.0
mm
SIEVE SIZE

Figure 27. Profiles of 4 "typical" spawning riffles in section G of Wampus Creek; midstream water velocities taken with a Pigmy Gurley current meter are superimposed; Wampus Creek, 1970.


velocity om/sec
depth cm
100
50
0
50
100
100
200
300
400
500
600
700
scale: 1mm=5cm


velocity cm/sec
depth cm
100
50
0
50
100
100
200
300
400
500
600


velocity cm/sec
depth cm
100
50
0
50
100
100
200
300
400
500
600


velocity cm/sec
depth cm
150
100
50
0
50
100
100
200
300
400
500
600

particularly conducive to maximum interchange of surface and intragravel water (Vaux, 1962) ensuring an adequate supply of oxygen for the developing eggs. Other areas, provided they exhibited sufficiently high water velocities and suitable gravel size and consistency, were utilized also but to a much lesser extent. Depth of deposition of eggs ranged from 2 to 6 cm.

Some observations of the spawning behavior of trout were made in both years. Features of the behavior of the female observed included nest digging activity, testing of the redd and defence of the redd area. Of the aggressive component of the male's behavior chasing, lateral and frontal display, parallel swimming and back-pedaling (Hanson and Smith, 1967) were noted. The most striking feature of the male's sexual behavior involves quivering against or near the female. The male places his head near the side of the female in the region between the anal and caudal fin and undergoes a series of violent, rhythmic muscular contractions that involve most of the body. Crossing over and under the female is also believed to be a feature of the sexual behavior of the male but may also have an aggressive component (Hartman, 1969). In terms of time spent, defence of the redd area against other males was the main activity of the spawning male. Three to 8 smaller males lying behind the spawning pair in a definite formation (see Hanson and Smith, 1967) were usually associated with them. Upon leaving of the pair the dominant satellite male would move up immediately and position itself in the redd only to be displaced by the returning spawners. Polygamy was observed in the case of one large male attending to two females spaced approximately 5 feet apart. In a group of fighting males the largest was usually the dominant one. When

disturbed the female would be the first to leave the redd area and would return some time after the male had resumed its activity of defending the nest.

These general observations on the spawning habits of the dwarfed rainbow trout show a close similarity to those of the large rainbows of the Lardeau River described by G. F. Hartman (1969).

FOOD

The results of the stomach analysis of tributary trout expressed in percent frequency of occurrence and percentage composition by numbers are presented in Table 11 and Figure 28. Chironominae and Orthocladinae larvae were found most frequently with mayfly larvae of the genus *Baetis*, terrestrial beetles, stonefly larvae of the genus *Alloperla*, and caddis fly larvae belonging to the family Limnephilidae ranking second, third, fourth and fifth in importance, respectively.

Numerically the small Diptera larvae were by far the most important, comprising 53.3 percent of the total of 4,333 organisms counted; larvae of the orders Ephemeroptera, Plecoptera and Trichoptera follow in that sequence. Terrestrial organisms constituted 10 percent by number of the food items identified. In terms of energy, however, terrestrial organisms, particularly beetles, because of their relatively large size, may be of much greater importance to the trout than their number suggests.

Discussion

In the tributaries trout appear to be opportunistic feeders taking advantage of drift and bottom food organisms. With the exception of trout

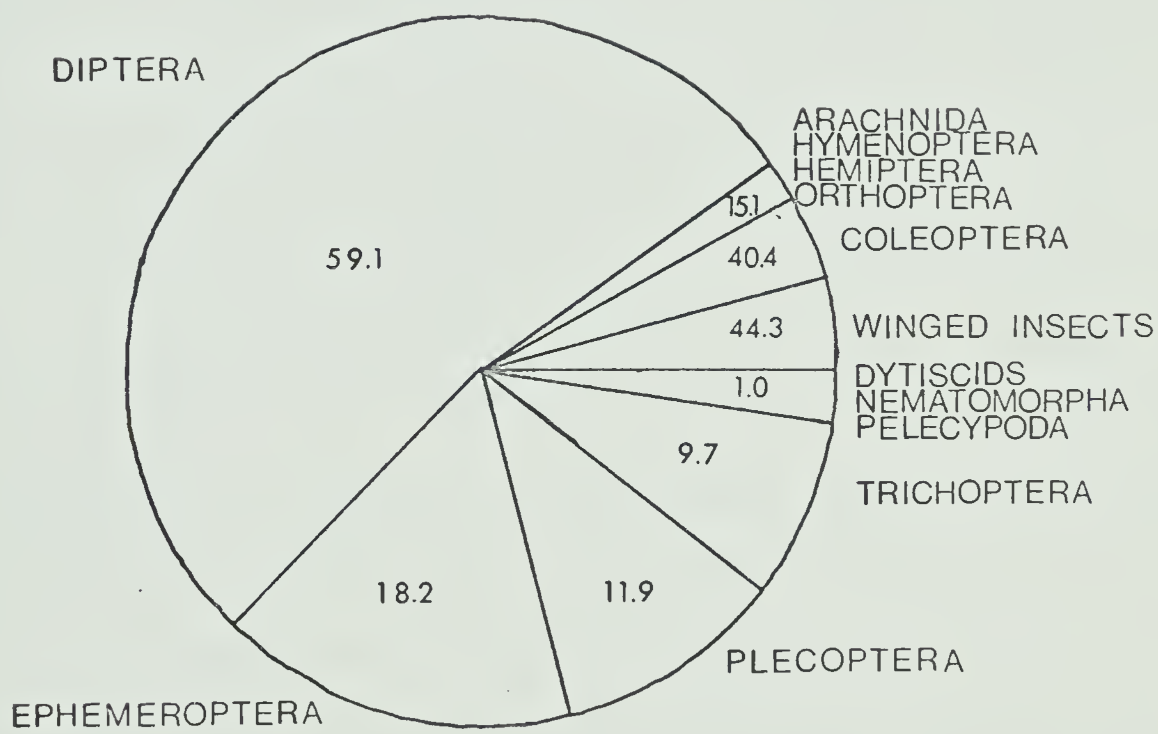
TABLE 11

PERCENT FREQUENCY OF OCCURRENCE OF FOOD ORGANISMS FOUND IN THE STOMACHS OF 100 TRIBUTARY RAINBOW TROUT

Food organism		Percent frequency of occurrence
Ephemeroptera	- *Baetis*	57
	Cinygmula	40
	Ephemeroptera heads	17
	Ephemerella	6
	Ameletus	4
Plecoptera	- *Alloperla*	51
	Isogenus	38
	Plecoptera heads	27
	Capnia	25
	Brachyptera	3
Trichoptera	- Limnephilidae	40
	Rhyacophilidae	33
	Trichoptera heads	24
	Brachycentridae	2
Diptera	- Chironominae, Orthocladinae	81
	Simuliidae	27
	Tipulidae	12
	Ceratopogonidae	10
Coleoptera		59
Hemiptera		9
Hymenoptera		8
Orthoptera		5
Arachnida		26
Nematomorpha		18
Winged insects*		37
Trout eggs		5
Ostracoda		1
Pelecypoda		1
Anostraca		1

*Adult Ephemeroptera, Plecoptera, Trichoptera and Diptera.

Figure 28. Percentage composition by numbers of the authochthonous fraction (Diptera, Ephemeroptera, Plecoptera, Trichoptera, Nematomorpha, Pelecypoda, Dytiscids) and the predominantly allochthonous fraction (Arachnida, Hymenoptera, Hemiptera, Orthoptera, Coleoptera, winged insects) of the food items in the stomachs of rainbow trout from the study streams.


DIPTERA
59.1
ARACHNIDA
HYMENOPTERA
HEMIPTERA
ORTHOPTERA
15.1
COLEOPTERA
40.4
WINGED INSECTS
44.3
DYTISCIDS
NEMATOMORPHA
PELECYPODA
1.0
9.7
TRICHOPTERA
11.9
PLECOPTERA
18.2
EPHEMEROPTERA

eggs their diet consists exclusively of invertebrates. In the table below the percentage composition by major orders of the stomach samples of trout is compared with that of a sample of aquatic insects taken with a fine-meshed dipnet over the period from June 1967 to June 1968 in Wampus Creek (Zelt, 1970).

Insect order	Percent of stomach sample	Mean percent of dipnet sample
Ephemeroptera	16.4	62.1
Plecoptera	10.7	15.6
Trichoptera	8.8	3.3
Diptera	53.3	14.7
Coleoptera	4.0	4.7

Assuming a similarity in composition of the aquatic insect communities of the three tributaries it appears that trout select for dipterans and trichopterans, with ephemeropterans and plecopterans being taken to a lesser extent than would be expected by their abundance. Samples of drift suggest that dipterans, particularly chironomids, are numerically very abundant which explains their relatively low abundance in dipnet samples. Mayflies are the dominant insect group in the dipnet samples and volumetrically appear to be the dominant organisms in the drift. In the diet of trout they are numerically the second most important food item.

The occurrence of one specimen of *Polyartemiella hazeni* (Murdoch) in the stomach of a trout caught in upper Wampus Creek in 1969 is of

interest since this species has not been previously reported outside the Arctic Circle. Transport of the organism to the stream in the egg stage by a migratory aquatic bird is a likely explanation for its presence (Daborn, pers. comm.).

Bottom feeding by trout is accomplished in quick, steep-angled dives during which the organism is plucked from the substrate or by combing through aquatic moss with its mouth partly open.

INCIDENTAL CATCH

Other fish species caught in the tributaries were Dolly Varden (*Salvelinus malma*), mountain whitefish (*Prosopium williamsoni*), burbot (*Lota lota*), brook trout (*Salvelinus fontinalis*), spoonhead sculpin (*Cottus ricei*), longnose sucker (*Catostomus catostomus*) and longnose dace (*Rhinichthys cataractae*).

Abundance

Of the above species only the Dolly Varden and the whitefish occurred in numbers large enough to attempt estimates of their abundance (Table 12); the others were caught only occasionally. In addition to these catches in Eunice Creek a survey on July 19, 1970, of sections B and C, a reach found to be virtually devoid of trout, produced 30 Dolly Varden and 94 whitefish.

Discussion

Generally Dolly Varden and whitefish were most abundant in Eunice Creek, the stream containing the lowest number of trout. The presence of ripe female Dolly Varden in August 1970 and of resident immature

TABLE 12

ABUNDANCE OF DOLLY VARDEN AND WHITEFISH IN THE STUDY STREAMS

Species	Stream	Sampling date	Section	m	c	r	$\hat{N} \pm 1$ S.E.
Dolly Varden	Wampus	August/70	A	17	8	4	34 ± 11
	Deerlick	July/70	A-E	23	33	13	58 ± 8
	Eunice	July/70	A	22	30	3	220 ± 112
Whitefish	Wampus	July/70	C,D	49	0	0	-
	Deerlick	June/70	A	12	15	1	-
	Eunice	July/70	A	71	57	35	116 ± 9

individuals indicates that this species utilizes the tributaries for spawning and rearing purposes. The presence of schools of whitefish in the three creeks was thought to be a result of random feeding movements of a type frequently observed in the McLeod River. All the species encountered in the McLeod River, with the exception of the Arctic grayling (*Thymallus arcticus*) were also present in the tributaries.

Growth and Length-Weight Relationships

Empirical growth curves of whitefish and Dolly Varden together with their length-weight relationships are presented in Figures 29, 30 and 31. The average fork length at age of the two species is detailed in Table 13.

Discussion

Growth of Dolly Varden from the tributaries and the river is compared to that of outmigrating Dolly Varden from Eva Creek, southeastern Alaska (Heiser, 1966) in Figure 31. The similarity in growth of this species from the two localities is interesting and suggests a similarity in growth conditions.

Figure 29. Growth of mountain whitefish (*Prosopium williamsoni*) in the study area, 1970.

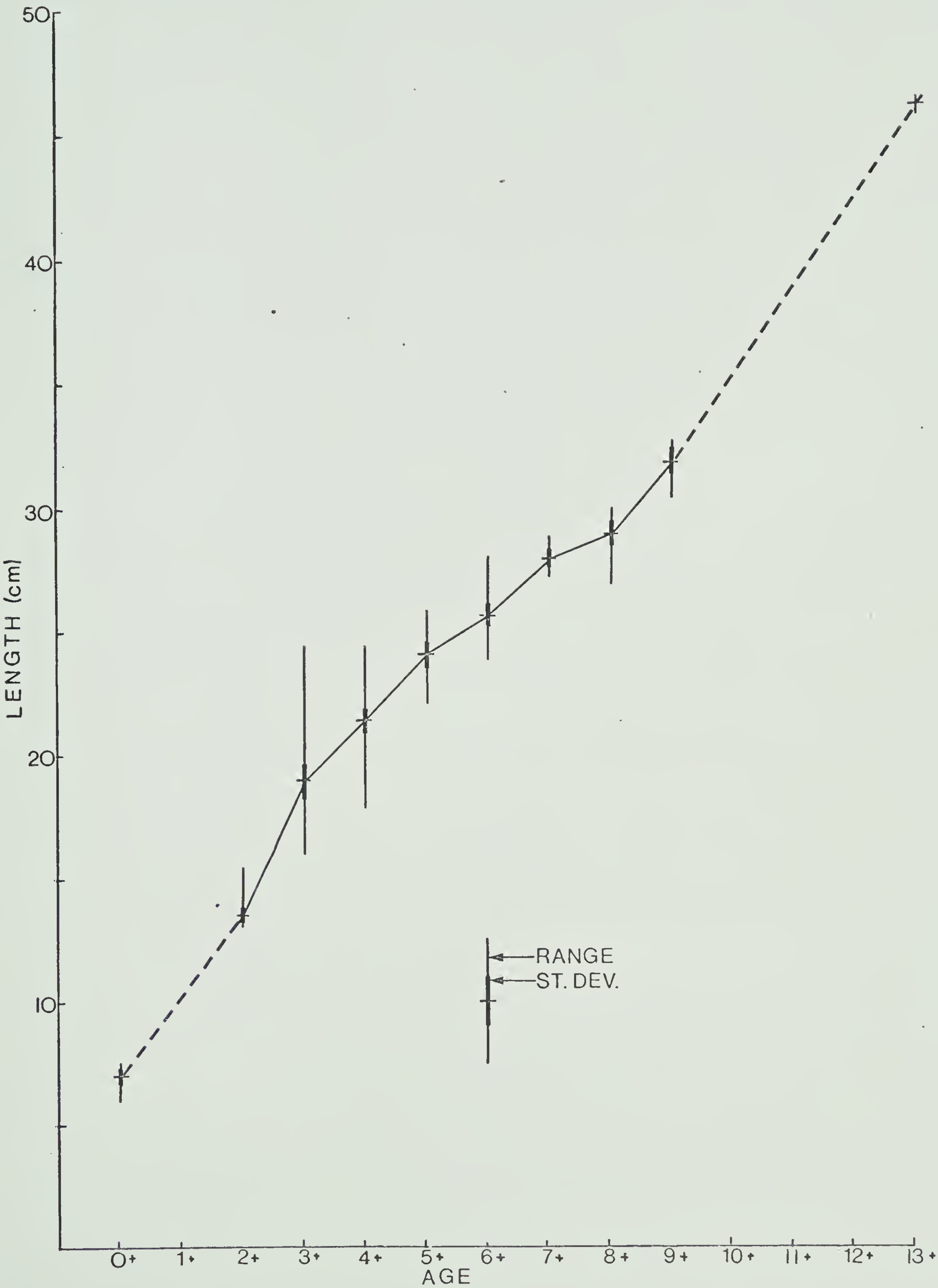
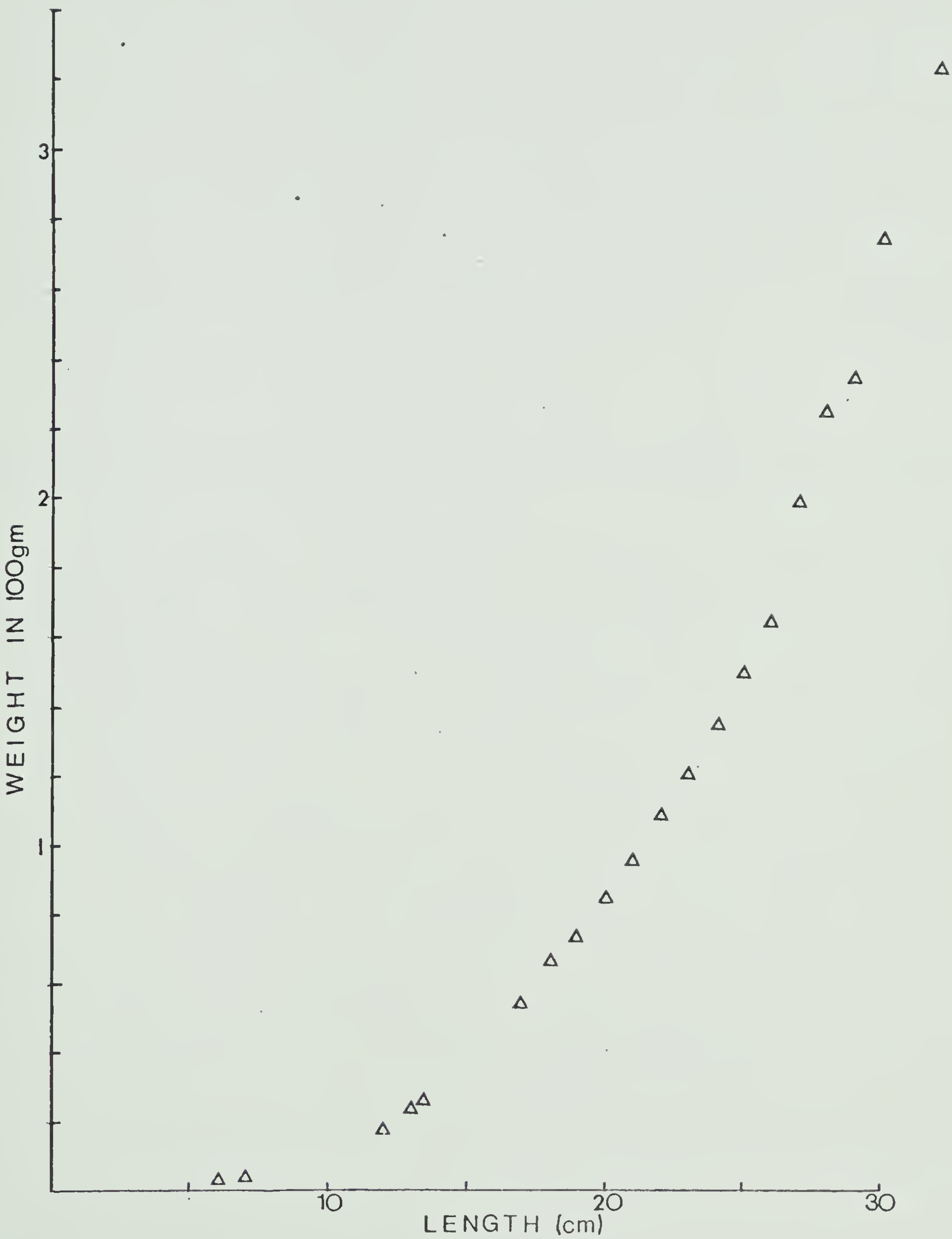

50
40
30
20
10
LENGTH (cm)
RANGE
ST. DEV.
0+
1+
2+
3+
4+
5+
6+
7+
8+
9+
10+
11+
12+
13+
AGE

Figure 30. Length-weight relationship of mountain whitefish collected in the 3 tributaries and the McLeod River, 1970.



WEIGHT IN 100gm
3
2
1
10
20
30
LENGTH (cm)

Figure 31. Growth of Dolly Varden collected in the McLeod River and the tributaries (Δ). Growth of the same species from south-eastern Alaska (o). Length-weight relationship for Dolly Varden (Δ) of the study area.

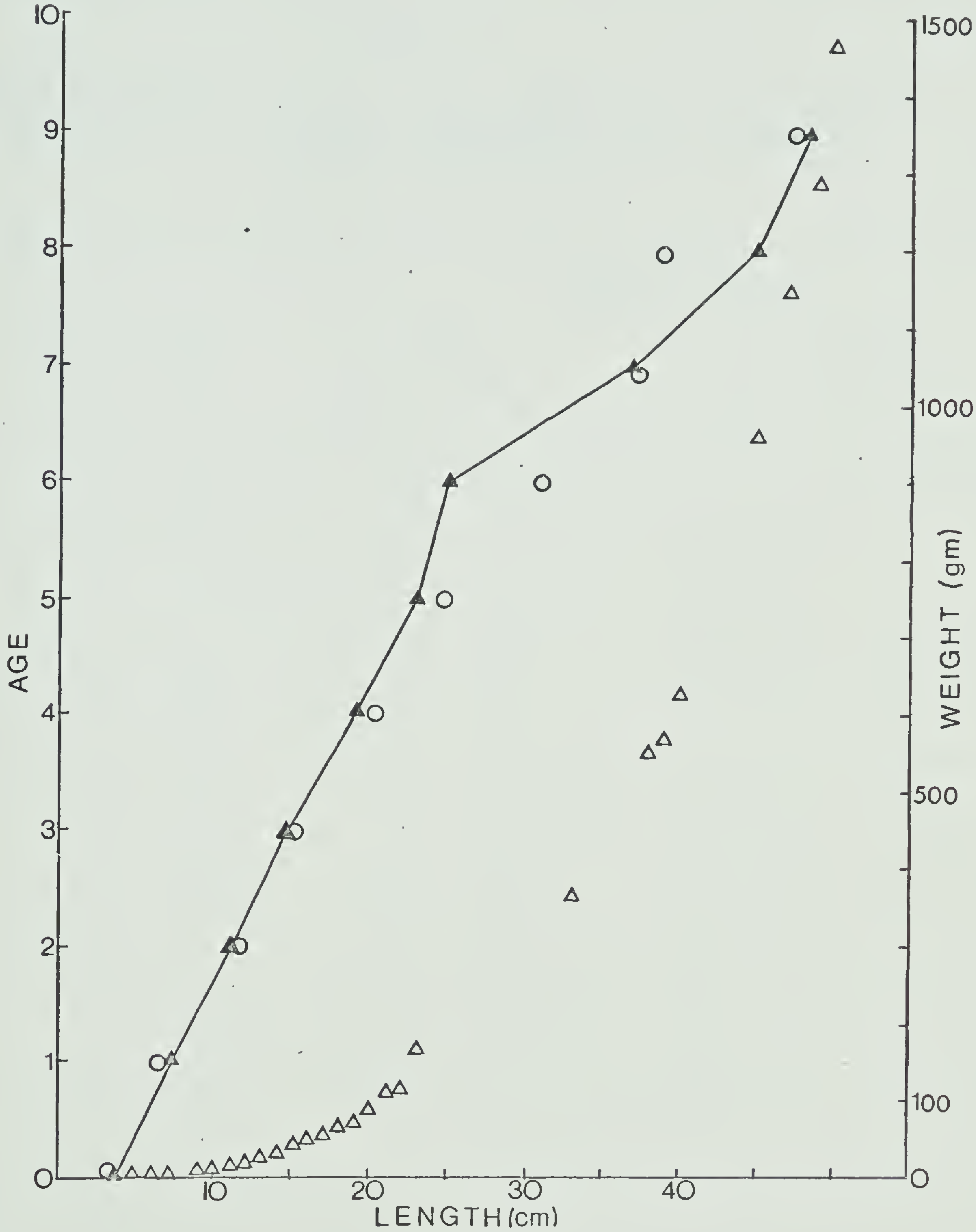

AGE
WEIGHT (gm)
LENGTH (cm)
0
1
2
3
4
5
6
7
8
9
10
10
20
30
40
100
500
1000
1500

TABLE 13

AVERAGE FORKLENGTH (CM) OF DOLLY VARDEN (D.V.) AND MOUNTAIN WHITEFISH (W) OF SAMPLES COLLECTED IN THE TRIBUTARIES AND THE McLEOD RIVER

Age group	No. of fish		Empirical length			
			Mean		Range	
	D.V.	W	D.V.	W	D.V.	W
0	1	12	3.8	6.9	-	5.9- 7.9
1	18	-	7.3	-	6.1- 8.1	-
2	40	4	11.1	13.6	9.2-12.6	13.0-15.6
3	17	106	14.8	18.9	12.0-19.1	16.1-24.4
4	17	116	18.9	21.6	15.9-23.6	18.0-24.5
5	5	34	22.9	24.2	21.8-24.7	22.2-26.0
6	2	29	24.9	25.7	24.6-25.2	24.1-28.2
7	3	4	37.3	28.0	33.1-40.3	27.3-29.0
8	7	6	45.0	29.0	39.1-50.5	27.1-30.1
9	5	3	48.0	31.9	45.0-49.5	30.5-32.8
10	-	1	-	46.5	-	-

GENERAL DISCUSSION

Recent ecological studies have revealed that the clearcutting of timber can have a profound physical and biological impact on a watershed. A maximum water temperature of 30° C and an average dissolved oxygen level of intragravel water of 1.3 mg/l, both lethal to salmonids, and a decline in a resident cutthroat population to approximately one-fourth of its previous abundance were recorded in a clearcut watershed in Oregon (Hall and Lantz, 1969).

The problem may be discussed from the point of view of requirements for the production of salmonids in streams and to what extent these requirements may be modified by the removal of timber.

The most obvious requirements for salmonid reproduction are oxygen-rich running water and a stable, relatively clean gravel substrate. Dissolved oxygen levels of at least 7 ppm, and preferably saturation levels, are necessary for the successful incubation and growth of eggs and alevins (McNeill, 1966). In general, the amount of oxygen reaching the developing eggs and fish larvae in the gravel beds depends on both oxygen concentration and water velocity (Wickett, 1954). Sediments washed into the creek from the surrounding clearcut terrain via roads and skid-trails tend to fill the interstices of the gravel resulting in a reduction of the oxygen level in the microhabitat of developing eggs and alevins and an inhibition of the removal of waste products. Deposition of silt in trout streams will also reduce the insect fauna and eliminate required shelter (Cordon and Kelley, 1961). Increased turbidity associated with increased suspended sediment loads may interfere with spawning and feeding

activities and generally reduce photosynthetic activity of green plants if turbidity is extensive in duration.

Higher peak flows in logged watersheds resulting from a decreased infiltration and water storage capacity of the soil mantle and the vegetation of the forest floor can be detrimental to fish production by scouring the spawning beds and reducing the food organisms (Allen, 1951). In contrast, higher average flows may be beneficial by providing increased living space during the summer period and by enlarging the catchment area for terrestrial insects. Furthermore, floods in an undisturbed watershed remove silt and organic materials from the gravel substrate and create cover by undercutting the banks and toppling trees growing along the watercourse.

Rainbow trout prefer temperatures between 13 and 13.6° C and temperatures in the 24 to 25° C range are lethal. Marked changes in the water temperature regime following logging as a result of removal of shade-giving riparian trees have been recorded. Increases in water temperature, provided they are not lethal, might be beneficial in some circumstances by increasing the primary productivity and thus the production of fish (Chapman, 1962). In addition, increases in the concentration of dissolved nutrients, particularly nitrates and phosphates resulting in an increase in algae production, may be expected after logging (Chapman, 1962).

Research results obtained in Oregon and Alaska may not be applicable to the foothills region of Alberta and therefore it is difficult to predict the effects of pulpwood logging on Alberta's headwater streams on the basis of findings made elsewhere. However, in view

of the extensive deposits of easily eroded silt-like glaciolacustrine sediments in the study area (Currie, 1969), a substantial increase of that material in the streams and a concomitant decline in the quality of the spawning substrate after logging to the stream banks can be expected. The relative absence of trout in Eunice Créek downstream from the access road to the drilling site is believed to be at least in part a reflection of this process of siltation. Old roads and seismic lines cut at right angles to the direction of flow of the creeks are at present the major sources of sediment (Figure 32). Besides reducing intragravel flows, sediments, by filling the intragravel space, appear to compact the gravel and make it unavailable to the small headwater trout for spawning. This difficulty is overcome by larger fish such as Dolly Varden and may explain their presence in sections almost devoid of rainbow trout. However, competition for a limited food supply and higher tolerance to reduced intragravel dissolved oxygen levels may also play an important role. Because of the shallow deposition depth of trout eggs (6 cm and less), increases in peak flows in response to logging and the associated scouring of the spawning riffles would be detrimental to trout production. It is apparent that clearcut logging modifies the essential requirements of the rainbow trout in such a way as to seriously interfere with their well being. The effect of a reduction in their numbers will be mediated in part by a decline in the available food supply resulting primarily from an increase in sedimentation after clearcut logging. An emergence of the Dolly Varden as the dominant species in the study streams is possible.

Observations made during a two-summer study of the three small Albertan foothills trout streams indicate: (a) the presence of discrete populations of rainbow trout; (b) the utilization of the creeks by Dolly

Figure 32. Erosion along seismic line in the Eunice Creek basin, 1969.

Varden for spawning and rearing; (c) the use of the creeks by trout residing in the mainstream for spawning; and (d) their role as a feeding ground for mountain whitefish. Thus any alteration affecting the quality of the habitat of the tributary streams will also be reflected in the level of abundance of the game fish populations of the mainstream. Although a watershed is a dynamic entity and possesses an inherent ability for rehabilitation, changes in the fish populations of the mountain streams as a result of clearcut logging will undoubtedly be long-term in the study area. Prudent logging practices such as the retention of unbroken buffer strips along the water courses may prove to be an essential and first step to better stream management.

LITERATURE CITED

Allen, K. R. 1951. The Horikiwi stream. A study of a trout population. N.Z. Marine Dept. Fish Bull. 10. 231 pp.

Alm, G. 1946. Reasons for the occurrence of stunted fish populations with special regard to the perch. Reports from the Swedish State Institute of Freshwater Fishery Research, Drottningholm, No. 25.

Aro, K. V., and G. C. Broadbent. 1950. Differences between egg counts of sockeye salmon at Lakelse and Babine Lakes. Prog. Rept. Pacific Cst. Stns., No. 32, pp. 17-19.

Bagenal, T. B. 1966. The ecological and geographical aspects of the fecundity of the plaice. J. mar. biol. Ass. U.K. 46:161-186.

Baxter, I. G. 1963. A comparison of the fecundities of early and late maturing stages of herring in the northeastern North Sea. Rapp. P.-v. Renn. Cons. perm. int. Explor. Mer 154:170-174.

Chapman, D. W. 1962. Effects of logging upon fish resources of the west coast. J. Forest. 60:533-537.

Cordone, A. J., and D. W. Kelley. 1961. The influence of inorganic sediment on the aquatic life of streams. California Fish and Game, Vol. 47, No. 2.

Currie, D. V. 1969. Hydrogeology of TRI-Creek Basin, Alberta. M.Sc. thesis, Department of Geology, University of Alberta, Edmonton, Alberta. 116 pp.

Dahl, K. 1918-19. Studies of trout and trout waters in Norway. Salm. Trout Mag. 17:58-79; 18:16-33.

Hall, J. D., and R. L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. In: Symposium on salmon and trout in streams. T. G. Northcote (ed.). H. R. MacMillan Lectures in Fisheries. 388 pp.

Hanson, A. J., and H. D. Smith. 1967. Mate selection in a population of sockeye salmon (*Oncorhynchus nerka*) of mixed age groups. J. Fish. Res. Bd. Canada 24:1955-1977.

Hartman, G. F. 1969. Reproductive biology of the Gerrard stock rainbow trout. In: Symposium on salmon and trout in streams. T. G. Northcote (ed.). H. R. MacMillan Lectures in Fisheries. 388 pp.

Haugen, G. 1966. Tri-creek fisheries watershed investigation. Alberta Department of Lands and Forests, Fish and Wildlife Division, Progress Report No. 1.

Heiser, D. W. 1966. Age and growth of anadromous Dolly Varden char (*Salvelinus malma*) in Eva Creek, Baranof Island, southeastern Alaska. Research Report No. 5. Alaska Department of Fish and Game, Juneau, Alaska.

Koski, K. V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in 3 Oregon coastal streams. M.S. thesis, Oregon State University. 84 pp.

Libosvarsky, J., and A. Łelek. 1965. Über die Artselektivität beim elektrischen Fischfang. Z. Fisch. 13:291-302.

McCart, P. 1967. Behavior and ecology of sockeye salmon fry in the Babine River. J. Fish. Res. Bd. Canada 24:375-428.

McFadden, J. T. 1961. A population study of the brook trout, *Salvelinus fontinalis*. Wildl. Monogr. 7, 73 pp.

McNeil, W. J. 1966. Effect of the spawningbed environment on reproduction of pink and chum salmon. U.S. Fish and Wildl. Serv., Fish Bull. 65: 495-523.

McNeil, W. J., and W. H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. U.S. Fish and Wildl. Serv., Spec. Sci. Rept. - Fish No. 490, 15 pp.

Nikolskii, G. V. 1969. Theory of fish population dynamics as the biological background for rational exploitation and management of fishery resources. Oliver and Boyd, London. 323 pp.

Parrish, B. B., and A.Saville. 1965. The biology of the north-east Atlantic herring populations. Oceanogr. mar. biol. A Rev., 3: 323-373.

Pope, J. A., D. H. Mills and W. M. Shearer. 1961. The fecundity of the Atlantic salmon (*Salmo salar* Linn.). Freshwat. Salm. Fish. Res. 26:1-12.

Robson, D. S., and H. A. Regier. 1964. Sample size in Petersen Mark and Recapture experiments. Trans. Amer. Fish. Soc. 93:215-226.

Robson, D. S., and H. A. Regier. 1968. Estimation of population number and mortality rates. In: Methods for Assessment of Fish Production in Fresh Waters. W. E. Ricker (ed.). Blackwell Scientific Publications, Oxford and Edinburgh.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Bd. Canada 119. 300 pp.

Scott, D. P. 1962. Effect of food quantity on fecundity of rainbow trout, *Salmo gairdneri*. J. Fish. Res. Bd. Canada 19:715-731.

Sheridan, W. J. 1962. Water flow through a salmon spawning riffle in southeastern Alaska. U.S. Fish and Wildl. Serv., Spec. Sci. Rept. - Fish No. 407, 20 pp.

Singley, W. J. P. 1957. The life history of the bullhead or Miller's thumb (*Cottus gobio* L.). Proc. Zool. Soc. Lond. 128:431-453.

Tebo, L. B., and W. W. Hassler. 1961. Seasonal abundance of aquatic insects in western North Carolina trout streams. J. Elisha Mitchell Sci. Soc. 77:249-259.

Vaux, W. G. 1968. Intragravel flow and interchange of water in a streambed. U.S. Fish and Wildl. Serv., Fish Bull. 66:479-489.

Zelt, K. A. 1970. The mayfly (Ephemeroptera) and stonefly (Plecoptera) fauna of a foothills stream in Alberta with special reference to sampling techniques. M.Sc. thesis, Department of Zoology, University of Alberta, Edmonton, Alberta. 93 pp.